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CONTENTS.

PAGE.

The Effects of Season and Frequency of Cutting on the Productivity of Various Grasses under Coastal Conditions in Northern Queensland. By J. L. SCHOFIELD 1

The Treatment of Little-leaf of Deciduous Fruit Trees. By K. M. WARD 59

A Ganoderma Root Rot of Citrus. By F. W. BLACKFORD 77

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THE QUEENSLAND JOURNAL OF AGRICULTURAL SCIENCE

VOL. 1. NO. 4.

DECEMBER, 1944

THE EFFECTS OF SEASON AND FREQUENCY OF CUTTING ON THE PRODUCTIVITY OF VARIOUS GRASSES UNDER COASTAL CONDITIONS IN NORTHERN QUEENSLAND.

By J. L. SCHOFIELD, B.Sc.

TABLE OF CONTENTS.

PAGE.

Summary 2

Introduction 3

Review of Previous Work 3

Experimental Procedure 4

Preparation of the Experimental Area 4

Grasses Used, and Height of Cutting 5

Planting 6

Layout 7

Maintenance of Stand 7

Method of Cutting, Weighing, and Drying 7

Fertilizer Applications in Second Year 7

Experimental Results 8

Method of Analysis 8

Effect of Season on Productivity 8

Effect of Frequency of Cutting on Productivity 15

Monthly Cuts 15

First 12 Months 15

Second 12 Months 18

Two-year Period 23

Two-monthly Cuts.. 23

First 12 Months 23

Second 12 Months 26

Two-year Period 29

Three-monthly Cuts 29

Variation in Yield in the Different Productivity Periods Under a System of Monthly Cutting 33

First 12 Months 34

Second 12 Months 36

Comparison of First and Second 12 Months 37

General Pattern of Productivity 39

Exceptions to the General Pattern of Productivity 41

PAGE.

Variations in Dry-matter Content as Influenced by Season and Frequency of Cutting 42
Monthly Cuts 42
Two-monthly Cuts 46
Three-monthly Cuts 47
Field Observations 50
Condition of Grasses at the Discard Cut 50
Inflorescence Emergence 51
Condition of Grasses in April-May, 1942, After Two Years Under Monthly Cutting 55
Acknowledgements 56
References 57

SUMMARY.

1. Nineteen perennial grasses were subjected to monthly, two-monthly, and three-monthly cutting treatments over a period of one or two years.

2. The grasses with two exceptions exhibit a phase of high productivity immediately following the period of establishment; thereafter each twelve months can be divided into four productivity periods: "rapid increase," "zenith," "rapid decrease," and "low."

3. The three main environmental factors controlling the pattern of productivity appear to be rainfall, temperature, and length of day.

4. There is a marked falling-off in yield during the second twelve months from April to the end of October, but a rapid increase in yield from November onwards as a result of fertilizer applications becoming effective. Panicum maximum var. typica and Digitaria milanjiana show a marked response to fertilizer applications.

5. Variations in yields of green matter and dry-matter are discussed in detail. In general the longer cutting rotation gives higher yields of green matter than the monthly cutting. The dry-matter content of the grasses is highest also in the longest cutting rotation. There is a negative correlation of dry-matter with yield over a considerable portion of the year.

6. The exceptional behaviour of Melinis minutiflora and Hyparrhenia aucta is discussed; it is shown that the latter grass possesses a different functional periodicity from that of the other grasses in the experiment.

7. The high dry-matter content of Cynodon plectostachyum under each rotation and in each productivity period is commented upon.

8. A summary of observations on inflorescence emergence indicates a wide range of variation, and in certain grasses the intensity and duration of inflorescence production is associated with high yield.

INTRODUCTION

The solution of the problems of grassland development in coastal northern Queensland, as in any other grassland area, is largely dependent upon a knowledge of the seasonal productivity and nutritive value of the various herbage species which can be grown successfully in that area. To quote Hammond (1938): "An extensive study of the duration of the rate of plant growth (made from monthly cuttings from a given area) with rainfall and temperature curves for all closely-settled districts in Australia is needed, in order that the possible areas for economic production of the various animal products may be delineated." The environmental conditions which govern economic grassland development are so varied and specialized in the coastal belt of northern Queensland that the problems of establishment, management and maintenance must be studied in each locality. The investigations described in this paper were carried out at the Bureau of Tropical Agriculture, South Johnstone, which is situated in what is known as the "wet belt" of coastal northern Queensland.

The most satisfactory gramineous and leguminous species for the development of grazing areas in the "wet belt" are not yet known with any degree of certainty. Initially, therefore, a series of broad preliminary surveys were undertaken with numerous herbage plants in order to select species for testing in adequately replicated plots under controlled conditions of grazing. The first survey carried out concerned introduced leguminous species and the results of this work have been published (Schofield, 1941). The next stage was a study of the productivity curves of a number of grasses in order to ascertain the effects of seasonal influences and cutting treatments. The nutritive value of many of these grasses was determined concurrently, and preliminary grazing trials with selected grass-legume mixtures were also conducted. In this paper, data relating to the reactions of various perennial grasses to season and to frequency of cutting are recorded and discussed.

REVIEW OF PREVIOUS WORK.

Stapledon (1924) and others have examined in detail the problems involved in contrasting the influences of different systems of cutting on grass productivity under temperate conditions. In the tropics, however, little work on the effect of season and of frequency of cutting on the yield of the various grasses included in this trial has been reported; indeed, for most of the grasses the information on yield is scanty.

It is reported from Guam (Briggs, 1921) that the highest recorded annual yield for *Brachiaria purpurascens* over a period of 42 months was an average of about 35 tons of forage per acre. Paterson (1933, 1935, 1936, 1937, 1938, 1941) at Trinidad has carried out a number of important researches on tropical fodder grasses. He reported a yield of 40 tons per acre per annum for *Brachiaria purpurascens* "when the cultural technique conforms to the one suggested as appropriate."

The green matter yield of *Chloris gayana* at hay stage in a fairly dry district in Queensland was given by Wells (1944) as 6 tons to 12 tons per acre. Lander (1942) in India showed that this grass yielded 5.26 tons of green matter per acre per annum when cut at monthly intervals, 5.34 tons when cut at two-monthly intervals, and 5.76 tons on a three-monthly cutting rotation.

Melinis minutiflora is reputed in Colombia (Boletin de Agricultura de Colombia, 1932) to give three or four cuttings, yielding 16-20 tons per acre per annum, while Obillo (1940) in the Philippines reported a yield in the year of establishment of less than 5 tons per acre. Milsum (1926) in Malaya obtained a yield of 9¼ tons per acre with this grass.

Jacobson (1914) stated that a yield of 48 tons of green matter per acre could be expected from *Panicum maximum*. In Malaya, the Department of Agriculture (1938) reported average yields of 13 tons of green matter per acre per annum from Guinea grass grown on sloping land and 16 tons on flat land, after the application of cattle manure at the rate of 10 tons or more per acre per annum. Simpson (1940) has discussed the possibility of a yield limit for a particular type of soil, irrespective of the rate of application of manure. He stated in his summary that "there would appear to be no correlation between yields of grass and planting distances between the limits of 4,840 and 10,890 plants per acre." Faulkner and Paterson (1942), in an interesting paper, have commented upon the very low yields obtained from tropical perennial fodder grasses in Malaya as compared with other places in the wet tropics, and they suggest that the growth and yield of the "grasses so far tried at Serdang are sub-normal and abnormal."

Paspalum dilatatum in southern Queensland has given yields of up to 16 tons of green matter per acre per annum under monthly cutting (Clydesdale, 1927).

Taylor (1938) has reported for *Pennisetum clandestinum* in South Africa an average annual yield over a period of three years of 4 tons of dry matter.

EXPERIMENTAL PROCEDURE.

Preparation of the Experimental Area.—The land selected for the experiments had been cropped with sugar cane for about 15 years, and planting of the experimental area was carried out following the harvesting of a third ratoon crop. Analyses of the alluvial granitic schist of the blocks (see Table 1) indicated that the soil was particularly acid and fairly low in its content of organic matter, nitrogen and phosphorus. Lime was applied for the purpose of correcting soil acidity and the mean pH was found to be 6.4 when determined early in the course of the experiment. Mechanical analysis gave the following figures:—Coarse sand, 4.9 per cent.; fine sand, 40.2 per cent.; silt, 30.7 per cent.; clay 15.8 per cent.; and organic matter, 8.4 per cent. The soil is readily pervious to moisture, but a hard, cement-like surface is formed after drying-out following rain. In fact,

the soil exhibits the unsatisfactory condition associated with lack of humus consequent on extended continuous cultivation without the beneficial effects of a long-term leguminous cover or a temporary ley. The following basal fertilizer dressing was applied in December, 1939:—

	Lb. Per Acre.			
		P_2O_5	N	K_2O
Superphosphate	168	37	..	..
Bone dust	56	13	2	..
Blood	28	..	3·4	..
Sulphate of ammonia	28	..	5·6	..
Sulphate of potash	28	..	..	14
	308	50	11	14

Grasses Used, and Height of Cutting.—To facilitate the cutting, weighing, drying and chemical analysis of the grasses, they were arranged into three groups or series, with an interval of approximately ten days between the cutting of each series in the respective rotations. This interval does not affect to any considerable degree the general interpretation of the results as to seasonal productivity or the analysis of variance of annual yield, because the interval is small in comparison with the marked seasonal changes which occur.

Apart from the preliminary discard cut carried out from late-March to mid-April, the height of cutting of the various grasses was approximately the height to which they would normally be grazed. The series arrangement of the grasses and the height of cutting were as shown hereunder:—

	Height of Cut in Inches.
Series I.—	
Cenchrus ciliaris L. (buffel grass)	2
Digitaria milanjiana Stapf (woolly finger grass)	2
Panicum maximum Jacq. No. 1202 (Hawaiian strain of Guinea grass)	12
Panicum maximum Jacq. No. 3783 (Hawaiian strain of Guinea grass)	6
Panicum maximum Jacq. var. *trichoglume* (slender Guinea grass)	4
Paspalum dilatatum Poir. (paspalum)	2
Urochloa bolbodes Stapf	2
Series II.—	
Brachiaria decumbens Stapf	2
Brachiaria purpurascens Raddi (Para grass)	2
Chloris gayana Kunth. No. 6586 (Rhodes grass—Commonwealth Plant Introduction ex Kenya)	4
Cynodon plectostachyum Pilg. (African star grass)	2
Hyparrhenia aucta (Stapf) Stapf ex Stent	2

Panicum maximum Jacq. No. 1200 (Hawaiian strain of Guinea grass) 8

Panicum maximum Jacq. var. *coloratum* C. T. White (purple-topped Guinea grass) 4

Series III.—

Chloris gayana Kunth. No. 6585 (Rhodes grass—Commonwealth Plant Introduction ex Kenya) 4

Melinis minutiflora Beauv. (molasses grass) 4

Panicum maximum Jacq. No. 3820 (Hawaiian strain of Guinea grass) 4

Panicum maximum Jacq. var. *typica* (common Guinea grass) .. 12

Pennisetum clandestinum Hochst. (Kikuyu grass) 2

Brachiaria purpurascens, Cenchrus ciliaris, Cynodon plectostachyum, and *Panicum maximum* Nos. 1200, 1202 and 3783, were grown for one year only, while the others were grown for two years.

Pennisetum purpureum Schum. (elephant or Napier grass) was included in the original plantings but was discarded after the ninth month because of infection by *Helminthosporium,* a parasitic fungus causing leaf damage. Infection was considerably more severe in the three-monthly cuttings than in the monthly cutting rotation.

Table 1.

Showing Analytical Data for the Soil of the Experimental Area.

Loss on ignition		7·8%
Organic carbon		1·88%
Organic matter		3·23%
Nitrogen		0·175%
Fe_2O_3, Al_2O_3, &c.	Sol. in HCl S.G. 1·1	23·8%
CaO		0·055%
MgO		0·20%
K_2O		0·376%
P_2O_5		0·153%
SiO_2		65·26%
Replaceable bases in milli-equivalents per 100 grams—		
Ca		0·1
K		0·26
Available P_2O_5 in p.p.m.		20
pH		4·6

Planting.—Planting was carried out in 1940 at the commencement of the wet season. All the grasses except *Pennisetum clandestinum* were planted from January 3 to January 18; *P. clandestinum* was planted on February 2. Seeds of *Cenchrus ciliaris, Chloris gayana, Melinis minutiflora, Panicum maximum*

Nos. 1200, 1202, 3783 and 3820, and *Paspalum dilatatum* were used; the remaining grasses were propagated by means of single sections of tillers.

Layout.—The grasses were planted in two blocks, each of which contained one plot of each of the grasses arranged at random. The plots were 30 feet long and 2 feet wide and consisted of a single row of plants in the case of the vegetatively propagated species. Discard rows were planted on the sides and ends of the plot and the three parallel rows of grass were separated from the neighbouring species by a pathway 4 feet wide. Each plot was divided into three sub-plots, which were cut at intervals of 30, 60 and 90 days, respectively. Davies (1931) showed that for a "natural" pasture in South Australia the optimum size of plot appeared to be 5 x 90 links (1/220 acre) and that the standard error was lower for long, narrow plots than for square, or nearly square, plots of equal area. As the experimental area at South Johnstone had been shown by previous cropping to be of reasonably uniform fertility, and as the error due to botanical composition is absent from plots of regularly-spaced plants of a single species, it was decided to use long, narrow plots of the dimensions indicated, *i.e.*, 30 feet by 2 feet.

Maintenance of Stand.—Stool counts carried out three and six months after planting showed that most of the plots which had been planted with vegetative material carried a full stand, and that plant mortality generally was very low. Weed growth was controlled by systematic hand-hoeing, inter-row scarification, and rotary-hoeing between the blocks.

Method of Cutting, Weighing, and Drying.—The grasses were cut with hand sheep shears. The discard rows were cut first and all the cut grass was removed prior to cutting and harvesting the centre rows. The cut herbage from the centre row in each of the plots due for harvest was placed on strips of hessian and transferred to the laboratory for weighing, after which a 2 lb. sample was selected by the random-grab sampling method. In the early cutting rotations, samples were dried in an electrical drier, but this method was discontinued, as air-drying in a scrimp bag beneath an iron roof, under conditions of good ventilation, was found to be quite satisfactory throughout the year. The grasses were air-dried until the weight was constant. No mould growth occurred on any of the grasses.

Fertilizer Applications in Second Year.—Pasture yield studies by many workers have shown that under cutting conditions yields during the second year are frequently lower than those of the first year. Thus, Stapledon and Davies (1930) stated: "The evidence as a whole, therefore, suggests that a diminution in 'pasture yield' will tend to take place progressively from one harvest year to the next under conditions of defoliation which remove everything from the sward and when no fertilizers are applied other than the initial dressing." In order to offset this anticipated falling-off in yield, which of course would tend to be accentuated under wet tropical conditions, fertilizer was applied immediately after each cut had been made during the second period of 12 months. The fertilizer applied consisted of a mixture of superphosphate

and blood dusted evenly over the whole of each sub-plot. The total amount was calculated for each grass on the basis of nutrients removed in the herbage during the first 12 months, as estimated from the crude protein and P_2O_5 analysis. Thus, 12 equal applications were made to the plots cut monthly, and six equal applications to the plots cut every two months. A relatively slow-acting source of nitrogen was selected for two reasons: (*a*) to obviate any undue influence on the general trend of the growth curve, and (*b*) to allow the depressing effect of the removal of the first year's harvest to manifest itself during the early part of the second year before fertilizer application became effective following the onset of favourable meteorological conditions.

EXPERIMENTAL RESULTS.

Method of Analysis.

The analysis of variance method has been employed to measure the standard error per plot in the different cutting rotations and to compare the yields of the various grasses. It has not been used, however, to test the yield of one cutting rotation against another, as there was no random arrangement of these treatments.

The chief source of error was slight hollows in the soil caused by ploughing operations. The experiment considered as a whole, however, has given reasonably close agreement between the replicates. The standard error per plot expressed as a percentage of the general mean for the monthly and two-monthly cutting rotations varies from 9.2 per cent. to 15.6 per cent., which indicates a sufficient degree of accuracy. In the three-monthly cutting rotation, however, the standard error is 26 per cent. of the general mean, and it is in these plots that the main error due to hollows in the ground occurred.

Effect of Season on Productivity.

To facilitate the presentation of the results of the experiment, the data for ten grasses have been selected for special study. These grasses are *Panicum maximum* var. *trichoglume* and *Paspalum dilatatum* (series I.); *Hyparrhenia aucta, Panicum maximum* var. *coloratum, Brachiaria decumbens, B. purpurascens* and *Chloris gayana* No. 6586 (series II.); *Pennisetum clandestinum, Panicum maximum* var. *typica* and *Melinis minutiflora* (series III.).

In Table 2 the yields of the above ten grasses, expressed as percentages of the total yield over two years (*Brachiaria purpurascens* one year only), have been grouped so that each year is divided into four productivity periods. Eight of the ten grasses follow a well-marked seasonal pattern of productivity, or similar growth rhythm. The two exceptions are *Hyparrhenia aucta* and *Melinis minutiflora*, the behaviour of which will be discussed later. The remaining eight grasses all show an initial phase of high productivity from 27-3-40 (date of discard cut, series I.) to 15-7-40 (date of cutting of series III.), when yields varying from 16 per cent. to 30 per cent. of the total yield over two years are obtained. In the next growth period, extending from

25-6-40 to 11-11-40, which corresponds to 118 days for each series, the yield is low and varies from 5 per cent. in the case of *Panicum maximum* var. *typica* to 15 per cent. with *Pennisetum clandestinum*. Then follows a period of rapid increase of productivity, extending from 22-10-40 to 10-1-41, in which productivity ranges from 7 per cent. with *Panicum maximum* var. *trichoglume* and *Paspalum dilatatum* to 11 per cent. with *Panicum maximum* var. *coloratum* over intervals of 58, 60 and 59 days respectively in each series. The next phase is one of high productivity from 20-12-40 to 10-4-41, covering an interval of 89-90 days, during which the yield percentages of the total productivity over two years vary from 18 with *Panicum maximum* var. *typica* to 23 with *Chloris gayana* No. 6586. A similar type of growth rhythm occurs in the second 12 months, except that a period of rapid decrease of productivity takes place from 20-6-41 to 6-11-41 instead of the period of high productivity noted in the phase immediately after establishment.

Stapledon (1924), in his studies on productivity at Aberystwyth, showed that the herbage year (temperate zone) may be divided into five well-defined periods: "awakening" period, "zenith" period, "gradually waning" period, "rapidly waning" period, and "dead season." The yield figures obtained in this experiment, and grouped as in Table 2, demonstrate that for many of the grasses under northern Queensland coastal conditions the year may be divided into four well-defined productivity periods. Following the system adopted by Stapledon, these four periods have been named to designate the type of productivity associated with each: (*a*) a period of rapid increase of yield from November to December ("rapid increase" period), (*b*) a period of high productivity from January to March ("zenith" period), (*c*) a period of rapid decrease of yield from April to June ("rapid decrease" period), and (*d*) a period of low productivity from July to October ("low productivity" period). There are, of course, no constant dates for the initiation and the conclusion of each productivity period: these will vary from year to year subject to the meteorological conditions and to the species. The months cited are the closest approximation which can be given on the data collected.

The meteorological factors which might be expected to contribute to variations in grass productivity throughout the year are rainfall, temperature and length of day. Particulars of the rainfall recorded at South Johnstone during the course of the experiment, of temperatures at Innisfail (situated 9 miles from South Johnstone) throughout that period, and of the calculated length of day at Innisfail are given in Table 3. Figures 1, 12 and 13 indicate that the period of highest rainfall occurs at a time of the year when temperatures are high and the days are long. Prescott (1938) has shown that, on the basis of the ratio of rainfall to saturation deficit, the length of the agricultural season at Innisfail in 12 months. During the wet season the combined effect of high temperature and the steady drift of the south-east trade wind following a period of heavy rainfall causes rapid moisture evaporation and a high transpiration rate. However, the water-absorbing capacity of the soil decreases considerably in the "rapid decrease"

Table 2.

Showing the Percentage Variation in Productivity over a Period of 24 Months of Individual Grasses Cut at Monthly Intervals and Grouped into Productivity Periods.

Date of Cut.	Number Days Growth.	Series.	Productivity Period.	Percentage Contribution to Productivity over 24 Months of Individual grasses.		
				Panicum maximum var. *trichoglume.*	*Paspalum dilatatum.*	Rainfall.
				Per cent.	Per cent.	
25/ 6/40	89	I	After establishment ..	26	23	31·55
22/10/40 (1st 12 months—)	118	I	Low	8	9	8·65
20/12/40 (1st 12 months—)	58	I	Rapid increase	7	7	5·57
21/ 3/41 (1st 12 months—)	90	I	Zenith	18	21	65·83
20/ 6/41	90	I	Rapid decrease	5	8	75·96
17/10/41 (2nd 12 months—)	118	I	Low	2	1	4·78
16/12/41 (2nd 12 months—)	59	I	Rapid increase	10	5	8·01
17/ 3/42 (2nd 12 months—)	90	I	Zenith	24	26	27·81
Total ..	712			100	100	

Date of Cut.	Number Days Growth.	Series.	Productivity Period.	*Hyparrhenia aucta.*	*Panicum maximum* var. *coloratum.*	*Brachiaria purpurascens.*	*Brachiaria decumbens.*	*Chloris gayana* No. 6586.	Rainfall.
5/ 7/40	91	II	After establishment ..	8	18	51	25	30	31·94
1/11/40 (1st 12 months—)	118	II	Low	16	6	10	10	12	4·79
31/12/40 (1st 12 months—)	60	II	Rapid increase	12	11	9	9	9	6·22
1/ 4/41 (1st 12 months—)	90	II	Zenith	24	22	30	20	23	81·07
30/ 6/41	89	II	Rapid decrease	2	3		4	5	60·81
27/10/41 (2nd 12 months—)	118	II	Low	3	1		1	3	4·04
29/12/41 (2nd 12 months—)	62	II	Rapid increase	10	9		8	6	8·24
25/ 3/42 (2nd 12 months—)	83	II	Zenith	25	30		23	12	28·32
Total ..	713			100	100		100	100	

				Pennisetum clandestinum.	*Panicum maximum* var. *typica.*	*Melinis minutiflora.*	Rainfall.
15/ 7/40	90	III	After establishment ..	20	16	11	26·92
11/11/40	118	III	Low	15	5	17	5·31
10/ 1/41	59	III	Rapid increase	8	10	14	9·33
10/ 4/41 (1st 12 months—)	89	III	Zenith	22	18	14	103·43
10/ 7/41	90	III	Rapid decrease	7	3	6	35·02
6/11/41	118	III	Low	1	1	3	4·77
7/ 1/42	61	III	Rapid increase	7	13	10	8·03
6/ 4/42 (2nd 12 months—)	87	III	Zenith	20	34	25	27·80
Total ..	712			100	100	100	

period from April to June compared with the "zenith" period from January to March, as a result of the cumulative effect of heavy rainfall and a decrease in the daily temperature. In fact, the extremely high moisture content of the soil in the "rapid decrease" period, and even in the latter portion of the "zenith" period, may act as a limiting factor to productivity under the climatic conditions of the Innisfail area. Table 4 shows that, in 1941, the April rainfall was particularly high at 41.19 inches and exceeded the average monthly rainfall of the "zenith" period by 14.17 inches. The figures illustrate the considerable variation which occurs in the April rainfall, a value that is rather critical in respect to soil moisture and its effect on growth in a season of high rainfall in the "zenith" period.

Table 3.

Showing Meteorological Data for the Innisfail–South Johnstone Area *

Rainfall in Inches at South Johnstone.

Month.	1940.	1941.	1942.	Average for 57 Years. Innisfail.
January	26·61	21·95	5·55	20·04
February	15·46	27·42	16·05	22·65
March	47·11	31·70	6·00	26·73
April	14·53	41·19	28·23	19·95
May	8·54	18·62	..	12·42
June	9·59	1·00	..	7·23
July	2·03	1·38	..	4·75
August	0·71	1·87	..	4·91
September	1·65	0·77	..	3·52
October	0·93	0·02	..	3·22
November	4·54	6·23	..	6·37
December	1·68	2·73	..	11·70
Total	133·38	154·88	..	143·49

Temperatures—Innisfail.

Mean Maximum.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1940	88·5	90·0	85·4	82·5	79·9	74·2	75·4	76·9	80·9	83·3	87·3	89·6	82·8
1941	87·7	87·3	86·5	80·5	77·0	75·2	75·3	75·5	80·2	84·1	86·1	88·2	82·0
1942	91·3	92·7	90·7	85·0	..	..	..	..	..	..	..	..	..
Average 26 years	87·8	87·1	85·4	82·9	79·5	76·6	75·5	77·2	80·3	83·5	85·8	87·7	82·4

Mean Minimum.

1940	72·3	74·2	71·4	69·2	64·6	63·0	57·2	58·2	58·7	61·5	67·8	70·1	65·7
1941	73·0	71·1	72·4	68·4	65·1	59·0	54·5	52·2	58·7	61·4	69·1	69·8	64·6
1942	71·8	73·4	70·0	69·8	..	..	..	..	..	..	..	..	..
Average 26 years	72·1	71·8	70·3	67·3	63·1	59·6	57·4	57·5	60·7	64·2	67·4	70·1	65·1

* Data for Innisfail supplied by the Commonwealth Meteorological Bureau.

Table 3—continued.

SHOWING METEOROLOGICAL DATA FOR THE INNISFAIL–SOUTH JOHNSTONE AREA—*continued.*

RELATIVE HUMIDITY—INNISFAIL.

Mean 9 a.m.

Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1940	87	86	89	91	88	92	87	87	82	76	74	74	84
1941	87	88	93	93	93	88	91	83	81	75	83	75	86
1942	76	79	86	89	..	..	..	..	..	..	..	..	..
Average 28 years	80	84	86	86	86	86	85	83	80	76	76	77	82

MONTHLY AVERAGE NUMBER OF HOURS SUNLIGHT PER DAY AT INNISFAIL (CALCULATED).

Hours and minutes ..	13·04	12·41	12·11	11·41	11·16	11·03	11·10	11·31	11·59	12·30	12·57	13·11	..

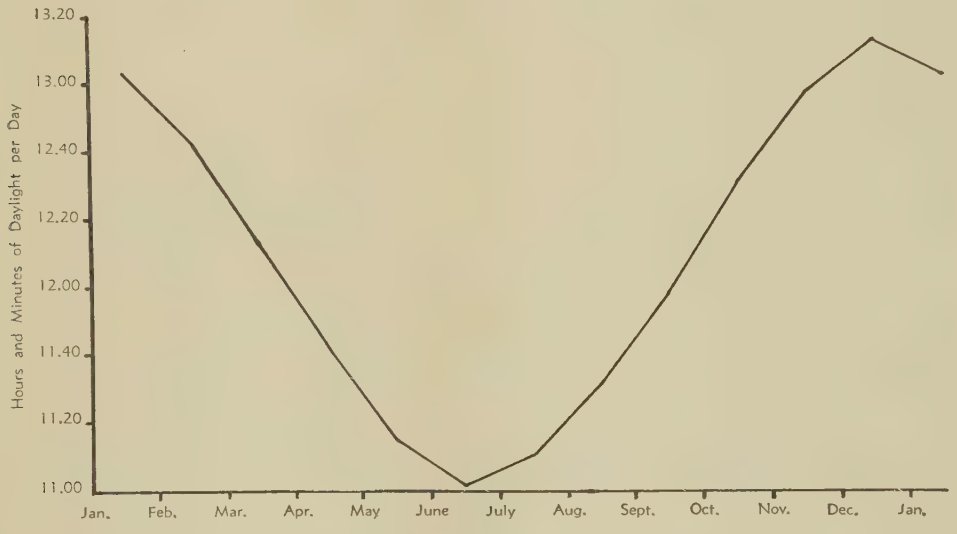

FIG. 1.

Showing the Average Number of Hours of Daylight Per Day in Each Month at Innisfail.

Table 4.

SHOWING AVERAGE MONTHLY RAINFALL IN INCHES DURING THE "ZENITH" PERIOD OF PRODUCTIVITY COMPARED WITH THE APRIL PRECIPITATION.

——	1940.	1941.	1942.	Average of 57 years.
January-March average monthly precipitation ("zenith" period)	29·73	27·02	9·20	23·14
April	14·53	41·19	28·23	19·95

Many examples may be quoted from Table 2 to show that the heavy rainfall received during March and April, 1941, has served to lower yield. *Panicum maximum* var. *trichoglume* is taken as typical. During the "rapid increase" period of 1940 this grass produced 7 per cent. of its total yield for 24 months;

the rainfall recorded during this period was 5.57 inches, during the previous period 8.65 inches, and for the two periods 14.22 inches. In the "zenith" period 18 per cent. of the total yield was produced; the rainfall during the period was 65.83 inches, making a total of 71.40 inches for the "rapid increase" and "zenith" periods. In the period of "rapid decrease" which followed, the yield was 5 per cent. of the total; the rainfall was 75.96 inches for the period and for that period and the previous period 141.79 inches.

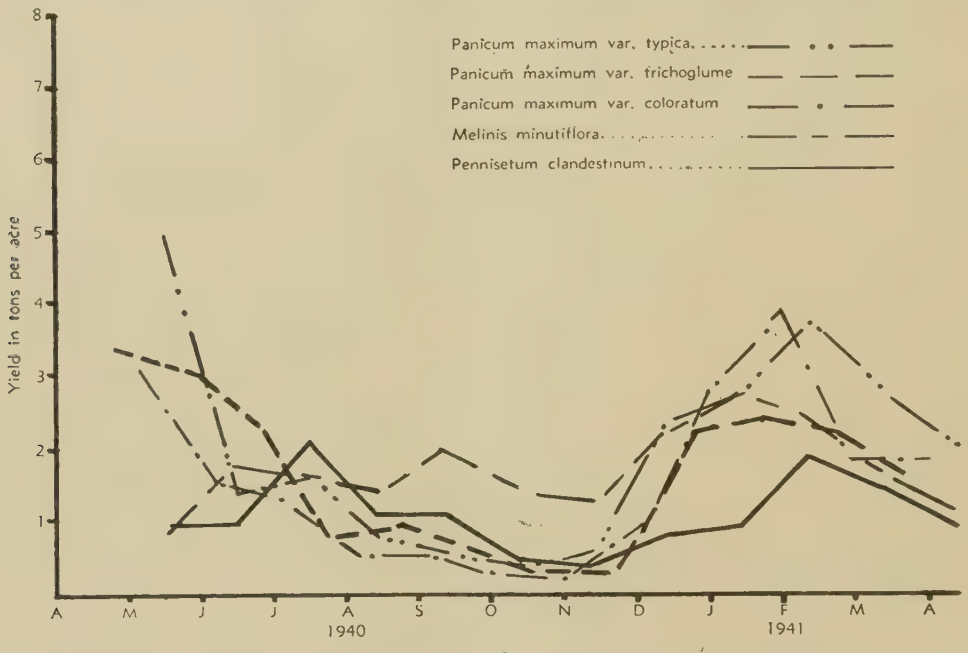

FIG. 2.

Showing Productivity Curves for the First 12 Months of *Melinis minutiflora, Panicum maximum* var. *coloratum, P. maximum* var. *trichoglume, P. maximum* var. *typica* and *Pennisetum clandestinum* cut at Monthly Intervals.

The relationships between meteorological factors and yield appear to be as follows:—The first phase of productivity—the "rapid increase" period (November-December)—results from the influence of the storm rains in October-November and the concurrent increase in temperature and length of day. This period is followed by a period of heavy rainfall, high temperatures and long days, corresponding to the early portion of the wet season, and culminates in productivity reaching its maximum value in the "zenith" period (January-March). Then occurs a "rapid decrease" period (April-June), which results from the combined effects of the following meteorological conditions:—(*a*) a period of high rainfall followed by a marked decrease in precipitation; (*b*) a gradual but steady decrease in temperature from March onwards; and (*c*) a steady decrease in the length of day. From July to October there is a "low productivity" period, where the chief limiting factor to increased growth after August is probably insufficient soil moisture resulting from low rainfall, since both length of day and temperatures are increasing. Investigations into

nitrate nitrogen accumulation in soils at South Johnstone, the results of which have not yet been published, suggest that yields during the "rapid increase" and "zenith" periods may be influenced by the fixation of nitrogen by soil organisms.

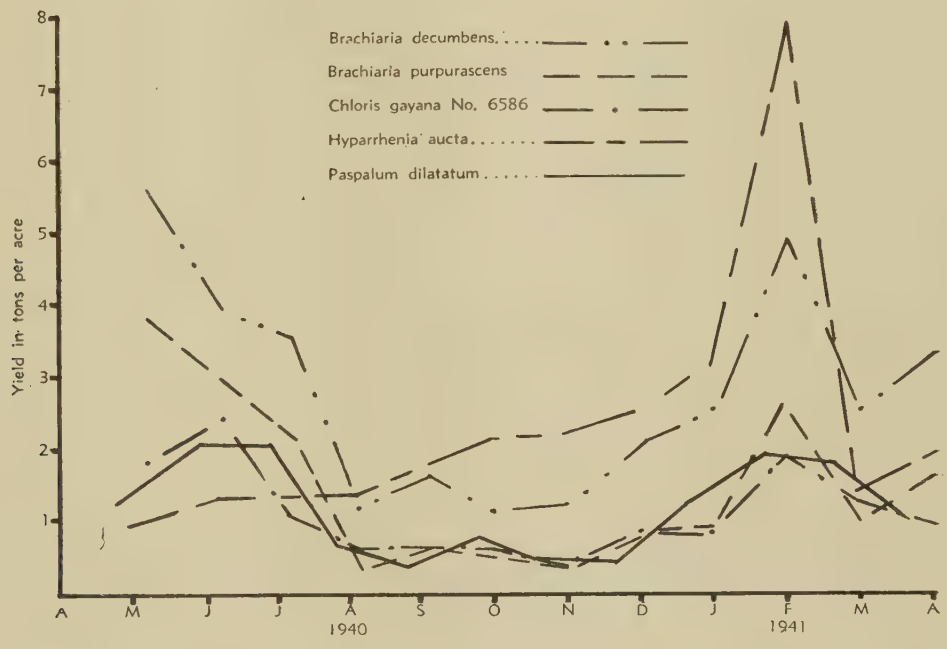

FIG. 3.

Showing Productivity Curves for the First 12 Months of *Brachiaria decumbens, B. purpurascens, Chloris gayana* No. 6586, *Hyparrhenia aucta* and *Paspalum dilatatum* cut at Monthly Intervals.

Effect of Frequency of Cutting on Productivity.

Monthly Cuts.

First 12 Months.—The yield of green matter in tons per acre, with the corresponding dry-matter percentage and dry-matter yield, for each cut during the first 12 months under a monthly cutting rotation are given in Table 5. The individual productivity curves of these grasses over the same period are shown in Figures 2 and 3. The behaviour of *Hyparrhenia aucta* and *Melinis minutiflora* is clearly different from that of the remainder of the grasses, whose curves illustrate the four productivity phases described previously. By means of the analysis of variance the total yields of all the grasses have been compared. The F value for varieties was shown to be highly significant and the results are summarized in Table 6. *Brachiaria decumbens* has a significantly higher yield (at the 1 per cent. level) than any of the other grasses except *Panicum maximum* Nos. 1202 and 3820 and *Hyparrhenia aucta.*

Table

SHOWING MONTHLY PRODUCTIVITY FIGURES FOR 12 MONTHS OF VARIOUS GRASSES IN TONS

Date of Cut.	Yield Green.	Dry-Matter. %	†Yield Dry.	Yield Green.	Dry-Matter. %	Yield Dry.	Yield Green.	Dry-Matter. %	Yield Dry.
Series I.	*Urochloa bolbodes.*			*Panicum maximum* var. *trichoglume.*			*Panicum maximum* No. 1202.		
26– 4–40 ..	2·08	20·8	*0·43	3·37	17·8	*0·60	1·94	22·7	*0·44
28– 5–40 ..	2·67	20·3	*0·54	3·11	18·4	*0·57	2·45	24·2	*0·59
25– 6–40 ..	2·42	17·2	*0·42	2·39	15·6	*0·37	1·85	20·3	*0·38
25– 7–40 ..	0·82	23·1	0·19	0·81	22·1	0·18	0·99	32·3	0·32
23– 8–40 ..	0·68	30·0	0·20	0·98	25·0	0·24	0·97	30·9	0·30
23– 9–40 ..	0·60	30·4	0·18	0·57	29·3	0·17	1·11	32·1	0·36
22–10–40 ..	0·64	30·7	*0·20	0·33	32·8	*0·11	0·71	34·4	*0·24
21–11–40 ..	1·26	32·8	0·41	0·32	37·6	0·12	1·04	38·0	0·39
20–12–40 ..	3·43	29·7	1·02	2·16	30·4	0·66	4·76	32·0	1·52
20– 1–41 ..	3·13	21·1	0·66	2·39	21·1	0·50	5·42	21·9	1·19
19– 2–41 ..	2·86	20·4	*0·58	2·23	19·9	*0·44	4·42	21·2	*0·94
21– 3–41 ..	2·31	18·8	0·43	1·55	20·3	0 31	3·17	21·9	0·69
Total	22·90	..	5·26	20·21	..	4·27	28·83	..	7·36
Series II.	*Hyparrhenia aucta.*			*Cynodon plectostachyum.*			*Panicum maximum* var. *coloratum.*		
6– 5–40 ..	1·00	21·6	*0·22	1·76	28·9	*0·51	3·04	19·9	*0·60
5– 6–40 ..	1·38	19·5	*0·27	1·67	30·5	*0·51	1·59	21·1	*0·34
5– 7–40 ..	1·43	19·5	*0·28	1·05	31·3	*0·33	1·29	25·0	*0·32
5– 8–40 ..	1·44	24·2	0·35	0·19	43·1	0·08	0·64	28·4	0·18
2– 9–40 ..	1·74	24·2	0·42	0·84	36·5	0·31	0·54	32·4	0·17
1–10–40 ..	2·17	27·3	0·59	0·50	42·8	0·21	0·33	40·9	0·13
1–11–40 ..	2·20	27·2	*0·60	0·55	48·4	*0·27	0·27	35·6	*0·10
2–12–40 ..	2·51	29·7	0·75	0·72	36·8	0·26	0·95	32·8	0·31
31–12–40 ..	3·22	36·7	1·18	0·92	38·0	0·35	2·70	34·4	0·93
30– 1–41 ..	7·92	16·8	*1·33	2·12	20·7	*0·44	3·81	15·5	*0·59
28– 2–41 ..	1·35	20·3	0·27	1·60	23·4	0·37	1·73	19·5	0·34
1– 4–41 ..	1·92	18·8	0·36	0·93	23·9	0·22	1·78	16·4	0·29
Total	28·28	..	6·62	12·85	..	3·86	18 67	..	4·30
Series III.	*Pennisetum clandestinum.*			*Panicum maximum* var. *typica.*			*Panicum maximum* No. 3820.		
16– 5–40 ..	0·93	21·3	*0·20	4·97	20·3	*1·01	3·01	21·3	*0·64
14– 6–40 ..	0·98	19·9	*0·19	1·36	21·1	*0·29	2·28	21·9	*0·50
15– 7–40 ..	2·07	24·2	*0·50	1·53	29·3	*0·45	1·05	25·4	*0·27
14– 8–40 ..	1·01	20·7	0·21	0·73	30·0	0·22	0·90	24·5	0·22
12– 9–40 ..	1·18	27·3	0·32	0·56	35·1	0·20	0·77	29·7	0·23
11–10–40 ..	0·49	32·8	0·16	0·43	43·9	0 19	0 75	38·1	0·29
11–11–40 ..	0·31	37·4	*0·12	0·55	39·2	*0·22	0·88	32·6	*0·29
11–12–40 ..	0·78	34·0	0·26	2·26	32·0	0·72	2·73	28·9	0·79
10– 1–41 ..	0·90	25·4	0·23	2·71	29·7	0·80	4·27	24·2	1·03
10– 2–41 ..	1·91	17·6	*0·34	3·71	22·6	*0·84	4·85	20·0	*0·97
11– 3–41 ..	1·40	15·6	0·22	2·69	22·7	0·61	2·74	20·3	0·56
10– 4–41 ..	0·96	17·2	0·16	2·15	23·4	0·50	1·92	22·7	0·44
Total ..	12·92	..	2·91	23·65	..	6·05	26·15	..	6·23

* Moisture-free figures.

† Air-dry figures contain from 2·1 to 3.8 % moisture with a mean of 3·2 %.

5.

PER ACRE GREEN MATTER WITH THE CORRESPONDING DRY-MATTER PERCENTAGES AND YIELDS.

Yield Green.	Dry-Matter. %	Yield Dry.	Yield Green.	Dry-Matter. %	Yield Dry.	Yield Green.	Dry-Matter. %	Yield Dry.	Yield Green.	Dry-Matter. %	Yield Dry.
Panicum maximum No. 3783.			*Digitaria milanjiana.*			*Paspalum dilatatum.*			*Cenchrus ciliaris.*		
2·77	19·0	*0·53	1·25	18·9	*0·24	1·25	20·6	*0·26	1·91	18·7	*0·36
3·71	21·9	*0·81	1·31	21·1	*0·28	2·03	19·5	*0·40	2·50	17·2	*0·43
1·69	18·8	*0·32	0·95	18·9	*0·18	2·01	19·9	*0·40	1·81	15·6	*0·28
0·54	31·0	0·17	0·33	27·9	0·09	0·68	29·2	0·20	0·34	27·0	0·09
0·70	30·6	0·21	0·52	33·3	0·17	0·35	35·2	0·12	0·26	39·7	0·10
0·61	36·1	0·22	0·43	33·3	0·14	0·61	38·8	0·24	0·44	39·7	0·17
0·58	35·1	*0·20	0·30	32·7	*0·10	0·44	36·4	*0·16	0·36	37 0	*0 13
0·70	39·3	0·27	0·40	43·4	0·17	0·46	47·5	0·22	0·45	45·4	0·20
2·88	28·9	0·83	1·69	31·2	0·53	1·19	35·1	0·42	1·28	32·8	0 42
3·33	21·1	0·70	2·83	21·1	0·60	1·97	24·2	0·48	2·67	17·2	0·46
2·32	20·3	*0·47	2·13	20·3	*0·43	1·84	22·7	*0·42	2·15	22·1	*0 47
1·96	23·4	0·46	1·51	23·4	0·35	1·02	21·1	0·21	1·11	25·0	0·28
21·79	..	5·19	13·65	..	3·28	13·85	..	3·53	15·28	..	3·39
Panicum maximum No. 1200.			*Brachiaria purpurascens.*			*Brachiaria decumbens.*			*Chloris gayana* No. 6586.		
1·63	22·2	*0·36	3·69	19·3	*0·71	5·60	20·6	*1·15	1·76	18·8	*0·33
1·79	20·5	*0·37	2·85	26·6	*0·76	3·78	21·9	*0·83	2·37	21·1	*0·50
1·56	22·1	*0·35	2·20	19·1	*0·42	3·55	18·8	*0·67	1·06	26·6	*0·28
1·01	26·4	0·27	0·37	28·6	0·11	1·19	26·6	0·32	0·60	23·9	0·14
0·82	29·8	0·24	0·61	27·5	0·17	1·56	32·0	0·50	0·61	27·3	0·17
0·81	31·8	0·26	0·49	36·9	0·18	1·12	32·8	0·37	0·53	34·8	0·18
0·63	28·9	*0·18	0·30	31·8	*0·09	1·34	33·8	*0·45	0·38	36·2	*0·14
0·99	29·0	0·29	0·75	27·3	0·20	2·10	25·8	0·54	0·75	34·3	0·26
1·28	32·8	0·42	0·84	28·2	0·24	2·54	35·9	0·91	0·78	22·3	0 17
2·04	16·3	*0·33	2·60	17·2	*0·45	4·82	16·4	*0·79	1·83	18·7	*0 34
1·24	17·3	0·21	1·00	20·3	0·20	2·45	21·1	0·52	1·22	21·1	0·26
0·79	17·5	0·14	1·64	16·4	0·27	3·28	18·0	0·59	0·98	16·4	0·16
14·59	..	3·42	17·34	..	3·80	33·33	..	7·64	12·87	..	2·93
Chloris gayana No. 6585.			*Melinis minutiflora.*								
3·46	20·0	*0·69	0·82	23·1	*0·19						
2·07	21·1	*0·44	1·70	21·5	*0·37						
1·96	25·4	*0·50	1·56	25·8	*0·40						
0·84	28·2	0·24	1·44	19·5	0·28						
0·65	29·2	0·19	2·00	25·8	0·52						
0·43	35·7	0·15	1·47	32·8	0·48						
0·37	34·9	*0·13	1·35	31·4	*0·42						
1·21	28·3	0·34	2·28	28·9	0·66						
1·88	26·6	0·50	2·70	22·7	0·61						
1·96	23·3	*0·46	2·38	21·6	*0·51						
1·46	22·7	0·33	1·67	18·8	0·31						
1·47	26·6	0·39	1·15	23·4	0·27						
17·76	..	4·36	20·52	..	5·02						

The yields obtained from certain grasses are substantially lower than those recorded for the same species in Trinidad (Paterson, 1938). In the Trinidad experiments, however, the nutrients applied as artificial fertilizer amounted to 55 lb. N, 50 lb. P_2O_5, and 65 lb. K_2O per acre, whereas in the Queensland experiments the corresponding amounts were 11 lb., 50 lb., and 14 lb. Furthermore, a third ratoon crop of sugar cane had been harvested from the experimental area just prior to laying down the grass plots.

Table 6.

MONTHLY CUT—FIRST 12 MONTHS.

Summary of Results—Green Matter.

Grass.	Mean Yield in Tons per Acre.	Percentage of Mean.	Significance Table.	
			1 per cent. Level.	5 per cent. Level.
1. *Brachiaria decumbens* ..	33·3	168·2	> Nos. 5–19	> Nos. 4–19
2. *Panicum maximum* No. 1202 ..	28·8	145·4	> Nos. 10–19	> Nos. 7–19
3. *Hyparrhenia aucta*	28·3	142·9	ditto	ditto
4. *Panicum maximum* No. 3820 ..	26·2	132·3	> Nos. 13–19	> Nos. 10–19
5. *Panicum maximum* var. *typica* ..	23·7	119·7	> Nos. 14–19	> Nos. 13–19
6. *Urochloa bolbodes*	22·9	115·6	> Nos. 15–19	> Nos. 13–19
7. *Panicum maximum* No. 3783 ..	21·8	110·1	> Nos. 17–19	> Nos. 13–19
8. *Melinis minutiflora*	20·5	103·5	No significant difference	> Nos. 15–19
9. *Panicum maximum* var. *trichoglume*	20·2	102·0	..	> Nos. 16–19
10. *Panicum maximum* var. *coloratum*	18·7	94·4	..	No significant difference
11. *Chloris gayana* No. 6585 ..	17·7	89·4	..	..
12. *Brachiaria purpurascens* ..	17·3	87·4	..	..
13. *Cenchrus ciliaris*	15·3	77·3	..	..
14. *Panicum maximum* No. 1200 ..	14·6	73·7	..	..
15. *Paspalum dilatatum*	13·8	69·7	..	..
16. *Digitaria milanjiana*	13·6	68·7	..	..
17. *Cynodon plectostachyum* ..	12·9	65·1	..	..
18. *Chloris gayana* No. 6586 ..	12·9	65·1	..	..
19. *Pennisetum clandestinum* ..	12·9	65·1	..	..
Mean	19·8	100·0	..	..
S.E.	2·18	11·01	..	..

Standard error of the difference between two means $= 11{\cdot}01\sqrt{2} = 15{\cdot}57$.

using the t test, $n = 18$ { 2·101 P = ·05 required difference 32·71; 2·878 P = ·01 44·81.

Second 12 Months.—Table 7 gives details of the yields obtained at each cut during the second 12 months, and the results of the analysis of variance applied to these figures are summarized in Table 8. The F value for varieties was shown to be highly significant.

The main point of interest in the above yields is the marked falling-off in productivity of all grasses during the second 12 months to the end of October. Reference to Table 3 shows that the rainfall during the months of August, September and October, 1940, was not markedly different from that of the corresponding months of 1941. Therefore, the rapid increase in yield which occurs from November onwards in the second year—shown by the marked

Table 7.

SHOWING MONTHLY PRODUCTIVITY FIGURES OF SELECTED GRASSES FOR SECOND 12 MONTHS IN TONS GREEN MATTER PER ACRE.

Date Cut. Series I.	*Urochloa bolbodes.*	*Panicum maximum* var. *trichoglume.*	*Digitaria milanjiana.*	*Paspalum dilatatum.*
Total 1st 12 months	22·90	20·21	13·65	13·85
21– 4–41	0·62	0·84	1·56	1·09
20– 5–41	0·44	0·39	0·62	0·52
20– 6–41	0·35	0·40	0·36	0·25
18– 7–41	0·13	0·17	0·09	0·06
18– 8–41	0·08	0·11	0·01	0·03
18– 9–41	0·21	0·30	0·10	0·10
17–10–41	0·12	0·15	0·13	0·04
17–11–41	1·13	1·52	0·61	0·48
16–12–41	2·06	1·90	1·45	0·65
15– 1–42	0·74	0·39	0·46	0·20
12– 2–42	5·56	5·61	3·96	2·92
17– 3–42	2·44	2·00	2·67	2·80
Total	13·88	13·78	12·02	9·14
Grand Total ..	36·78	33·99	25·67	22·99
Series II.	*Hyparrhenia aucta.*	*Panicum maximum* var. *coloratum.*	*Brachiaria decumbens.*	*Chloris gayana* No. 6586.
Total 1st 12 months	28·28	18·67	33·33	12·87
30– 4–41	0·28	0·56	0·57	0·34
30– 5–41	0·39	0·37	1·28	0·26
30– 6–41	0·33	0·17	0·43	0·19
29– 7–41	0·26	0·08	0·18	0·09
29– 8–41	0·23	0·07	0·07	0·13
26– 9–41	0·37	0·11	0·21	0·17
27–10–41	0·28	0·08	0·14	0·20
26–11–41	2·19	1·34	2·81	0·58
29–12–41	2·45	1·53	1·40	0·52
28– 1–42	2·85	2·57	3·25	0·52
23– 2–42	7·42	5·60	6·27	1·20
25– 3–42	1·06	1·48	2·26	0·28
Total	18·11	13·96	18·87	4·48
Grand Total ..	46·39	32·63	52·20	17·35

Table 7—continued.

SHOWING MONTHLY PRODUCTIVITY FIGURES OF SELECTED GRASSES FOR SECOND 12 MONTHS IN TONS GREEN MATTER PER ACRE—*continued.*

Series III.	*Pennisetum clandestinum.*	*Panicum maximum* var. *typica.*	*Chloris gayana* No. 6585.	*Melinis minutiflora.*
Total 1st 12 months	12·92	23·65	17·76	20·52
9– 5–41	0·70	0·74	0·68	1·04
9– 6–41	0·46	0·30	0·55	0·74
10– 7–41	0·24	0·23	0·23	0·23
8– 8–41	0·08	0·11	0·11	0·17
9– 9–41	0·01	0·17	0·06	0·21
7–10–41	0·05	0·23	0·04	0·51
6–11–41	..	0·30	..	0·25
5–12–41	0·80	4·19	0·74	2·78
7– 1–42	0·49	1·95	0·69	0·97
4– 2–42	1·83	5·88	0·85	4·47
6– 3–42	1·78	6·99	1·00	2·40
6– 4–42	0·33	3·54	0·57	1·97
Total	6·77	24·63	5·52	15·74
Grand Total ..	19·69	48·28	23·28	36·26

Table 8.

MONTHLY CUT—SECOND 12 MONTHS.

Summary of Results—Green Matter.

Grass.	Mean Yield in Tons per Acre.	Percentage of Mean.	Significance Table. 1 per cent. Level.	Significance Table. 5 per cent. Level.
1. *Panicum maximum* var. *typica* ..	24·6	187·8	>Nos. 2–12	..
2. *Brachiaria decumbens*	18·9	144·3	>Nos. 6–12	>Nos. 5–12
3. *Hyparrhenia aucta*	18·1	138·2	>Nos. 8–12	>Nos. 5–12
4. *Melinis minutiflora*	15·7	119·8	>Nos. 9–12	>Nos. 8–12
5. *Panicum maximum* var. *coloratum* ..	14·0	106·9	>Nos. 10–12	>Nos. 9–12
6. *Urochloa bolbodes*	13·9	106·1	ditto	ditto
7. *Panicum maximum* var. *trichoglume* ..	13·8	105·3	ditto	ditto
8. *Digitaria milanjiana*	12·0	91·6	>Nos. 10–12	..
9. *Paspalum dilatatum*	9·1	69·5	No significant difference	>Nos. 11 and 12
10. *Pennisetum clandestinum*	6·8	51·9		No significant difference
11. *Chloris gayana* No. 6585	5·5	42·0	..	..
12. *Chloris gayana* No. 6586	4·5	34·3	..	..
Mean	13·1	100·0	..	..
S.E.	1·13	8·62	..	..

Standard error of the difference between two means $= 8{\cdot}62\sqrt{2} = 12{\cdot}19$

using the t test, n = 11 $\begin{cases} 2{\cdot}201\ P = {\cdot}05 \text{ required difference } 26{\cdot}83 \\ 3{\cdot}106\ P = {\cdot}01 \qquad\qquad\quad 37{\cdot}86. \end{cases}$

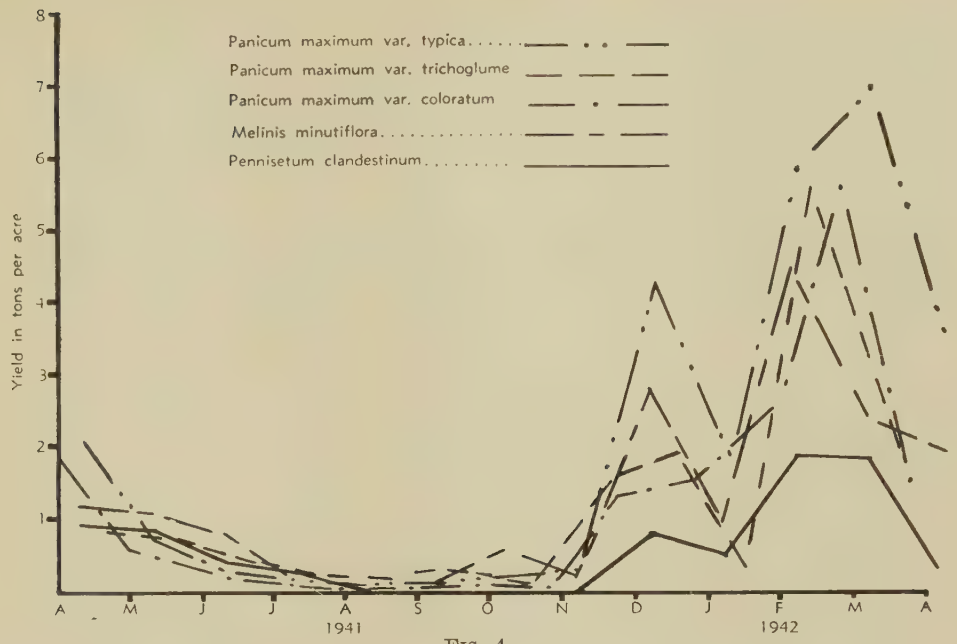

FIG. 4.

Showing Productivity Curves for the Second 12 Months of *Melinis minutiflora*, *Panicum maximum* var. *coloratum*, *P. maximum* var. *trichoglume*, *P. maximum* var. *typica* and *Pennisetum clandestinum* cut at Monthly Intervals.

FIG. 5.

Showing Productivity Curves for the Second 12 Months of *Brachiaria decumbens*, *Chloris gayana* No. 6586, *Hyparrhenia aucta* and *Paspalum dilatatum* cut at Monthly Intervals.

increase in the angle of slope of the productivity curves from this month (see Figures 4 and 5) as compared with the same period in the first year (see Figures 2 and 3)—leads to the conclusion that fertilizer application is becoming effective. However, the combined effect of fertilizer application and favourable meteorological conditions during the latter portion of the second 12 months is not sufficient to compensate for the low yields experienced from April to November. As a result, all grasses with the exception of *Panicum maximum* var. *typica* show a considerable reduction in productivity over the second 12 months, in spite of repeated fertilizer applications. The extent of the reduction is shown in Table 9,

Table 9.

SHOWING THE YIELDS OF GREEN MATTER FROM MONTHLY CUTS OVER THE FIRST 12 MONTHS COMPARED WITH THOSE FOR THE SECOND 12 MONTHS AND WITH TWO-MONTHLY AND THREE-MONTHLY CUTTING ROTATIONS.

Grass.	Monthly Cuts First 12 Months—Total Yield Green Matter in Tons Per Acre. (1)	Yields Expressed as a Percentage of Column 1.			
		Two-monthly Cuts First 12 Months. (2)	Three-monthly Cuts First 12 Months. (3)	Monthly Cuts Second 12 Months. (4)	Two-monthly Cuts Second 12 Months. (5)
Panicum maximum var. *typica* ..	23·7	83	116	104	89
Panicum maximum var. *trichoglume*	20·2	79	92	68	49
Panicum maximum var. *coloratum* ..	18·7	129	84	75	89
Brachiaria decumbens	33·3	137	159	57	65
B. purpurascens	17·3	120	128	..	..
Hyparrhenia aucta	28·3	113	106	64	57
Melinis minutiflora	20·5	99	130	77	75
Pennisetum clandestinum	12·9	97	106	53	50
Chloris gayana No. 6586	12·9	101	153	35	54
Paspalum dilatatum	13·9	129	122	66	77

where the yields in the second 12 months are expressed as percentages of the figures for the first 12 months. These figures show that the greatest reduction in yield (65 per cent.) occurred with *Chloris gayana* No. 6586, and that the least reductions were shown by *Melinis minutiflora* (23 per cent.) and *Panicum maximum* var. *coloratum* (25 per cent.). The reduction in yield of 43 per cent. by *Brachiaria decumbens* during the second 12 months indicates the severe drain on soil nutrients caused by the relatively high yield of the first year.

Another point of interest concerning the yield for the second 12 months is the marked increase in yield of *Panicum maximum* var. *typica* during the "zenith" period, which has resulted in this grass giving the greatest yield. Table 2 shows that 34 per cent. of the total yield of *Panicum maximum* var. *typica* for 24 months was obtained during the "zenith" period of 1942 (January 7-April 6). This high proportion of the total yield is easily the largest among the ten grasses selected, and it is indicative of the strong reaction of *Panicum maximum* var. *typica* to the fertilizer application. This is a point which will be commented upon further under the two-monthly cutting rotation. The mean daily yield

of 422 lb. (Table 18) during the "zenith" period of the second 12 months is additional proof of the greatly accelerated rate of growth of this grass.

The reduction in yield, amounting to 65 per cent., suffered by *Chloris gayana* No. 6586 points to the unsuitability of this strain to the very wet zone of coastal northern Queensland. This is in accord with general field experience in that area.

Two-year Period.—The yield figures for the whole period of two years have been examined by the analysis of variance method and the results are summarized in Table 10. Varietal effect is highly significant. *Brachiaria*

Table 10.

Monthly Cut over Two Years.

Summary of Results—Green Matter.

Grass.	Mean Yield in Tons per Acre.	Percentage of Mean.	Significance Table.	
			1 per cent. Level.	5 per cent. Level.
1. *Brachiaria decumbens*	52·2	158·2	>Nos. 4–12	..
2. *Panicum maximum* var. *typica* ..	48·3	146·4	ditto	..
3. *Hyparrhenia aucta*	46·4	140·6	ditto	..
4. *Urochloa bolbodes*	36·8	111·5	>Nos. 8–12	..
5. *Melinis minutiflora*	36·3	110·0	ditto	..
6. *Panicum maximum* var. *trichoglume* ..	34·0	103·0	>Nos. 9–12	>Nos. 8–12
7. *Panicum maximum* var. *coloratum* ..	32·6	98·8	>Nos. 10–12	>Nos. 8–12
8. *Digitaria milanjiana*	25·7	77·9	No significant difference	>No. 12
9. *Chloris gayana* No. 6585	23·3	70·6	..	No significant difference
10. *Paspalum dilatatum*	23·0	69·7	..	..
11. *Pennisetum clandestinum*	19·7	59·7	..	..
12. *Chloris gayana* No. 6586	17·3	52·4	..	..
Mean	33·0	100·0	..	..
S.E.	2·14	6·48	..	..

Standard error of the difference between two means $= 6{\cdot}48\sqrt{2} = 9{\cdot}16$

using the t test, $n = 11$ { 2·201 P = ·05 required difference 20·16; 3·106 P = ·01 28·45

decumbens, Panicum maximum var. *typica* and *Hyparrhenia aucta* are the highest yielding grasses; the lowest yielding are *Chloris gayana* Nos. 6585 and 6586, *Paspalum dilatatum* and *Pennisetum clandestinum.*

Two-monthly Cuts.

First 12 Months.—The detailed yields of the various grasses under a two-monthly cutting rotation during the first 12 months are given in Table 11 and the productivity curves of these grasses for the same period are shown in

Table 11.

Showing Two-monthly Productivity Figures of Various Grasses for 12 Months in Tons Green Matter per Acre.

Series I. Date Cut.	*Urochloa bolbodes.*	*Panicum maximum* var. *trichoglume.*	*Panicum maximum* No. 1202.	*Panicum maximum* No. 3783.	*Digitaria milanjiana.*	*Paspalum dilatatum.*	*Cenchrus ciliaris.*
28– 5–40 ..	6·96	4·60	5·59	9·62	2·61	4·28	5·70
25– 7–40 ..	2·10	2·35	1·90	1·92	1·47	2·22	1·28
23– 9–40 ..	1·60	1·47	1·63	1·44	0·76	1·37	0·71
21–11–40 ..	2·18	0·55	1·28	1·30	0·76	0·95	0·76
20– 1–41 ..	8·33	4·18	11·67	7·89	5·49	4·68	4·54
21– 3–41 ..	5·58	2·80	8·17	5·06	4·22	4·35	3·71
Total ..	26·75	15·95	30·24	27·23	15·31	17·85	16·70

Series II. Date Cut.	*Hyparrhenia aucta.*	*Cynodon plectostachyum.*	*Panicum maximum* var. *coloratum.*	*Panicum maximum* No. 1200.	*Brachiaria purpurascens.*	*Brachiaria decumbens.*	*Chloris gayana* No. 6586.
5– 6–40 ..	3·06	3·62	5·51	3·21	5·99	15·83	4·04
5– 8–40 ..	3·09	1·81	2·31	2·58	2·14	2·18	1·23
1–10–40 ..	4·00	1·81	1·08	1·73	1·44	4·14	1·25
2–12–40 ..	4·46	1·34	1·44	2·34	1·50	3·50	0·77
30– 1–41 ..	13·57	4·16	9·22	4·19	6·52	13·53	3·60
1– 4–41 ..	3·70	3·57	4·54	2·36	3·24	6·32	2·07
Total ..	31·88	16·31	24·10	16·41	20·83	45·50	12·96

Series III. Date Cut.	*Pennisetum clandestinum.*	*Panicum maximum* var. *typica.*	*Panicum maximum* No. 3820.	*Chloris gayana* No. 6585.	*Melinis minutiflora.*
14– 6–40 ..	2·39	6·10	7·98	5·96	4·31
14– 8–40 ..	2·45	1·34	1·73	2·08	2·70
11–10–40 ..	0·96	0·81	1·41	1·56	2·16
11–12–40 ..	1·15	2·32	3·16	2·01	3·52
10– 2–41 ..	2·48	6·19	8·88	6·23	5·36
10– 4–41 ..	3·09	2·93	3·75	3·87	2·32
Total ..	12·52	19·69	26·91	21·71	20·37

Figures 6 and 7. The curves show that, except for *Hyparrhenia aucta,* the same four productivity phases occur under a system of two-monthly cutting as in the monthly cutting rotation. *Melinis minutiflora* under a two-monthly cutting rotation follows the same general productivity curve as the other grasses, in contrast to its behaviour under monthly cutting. *Hyparrhenia aucta* shows no reduction in yield from June onwards corresponding to the "low" period of productivity common to the other grasses.

The analysis of variance has been applied to the yield totals given in Table 11 and the results are summarized in Table 12. Varietal effect is highly

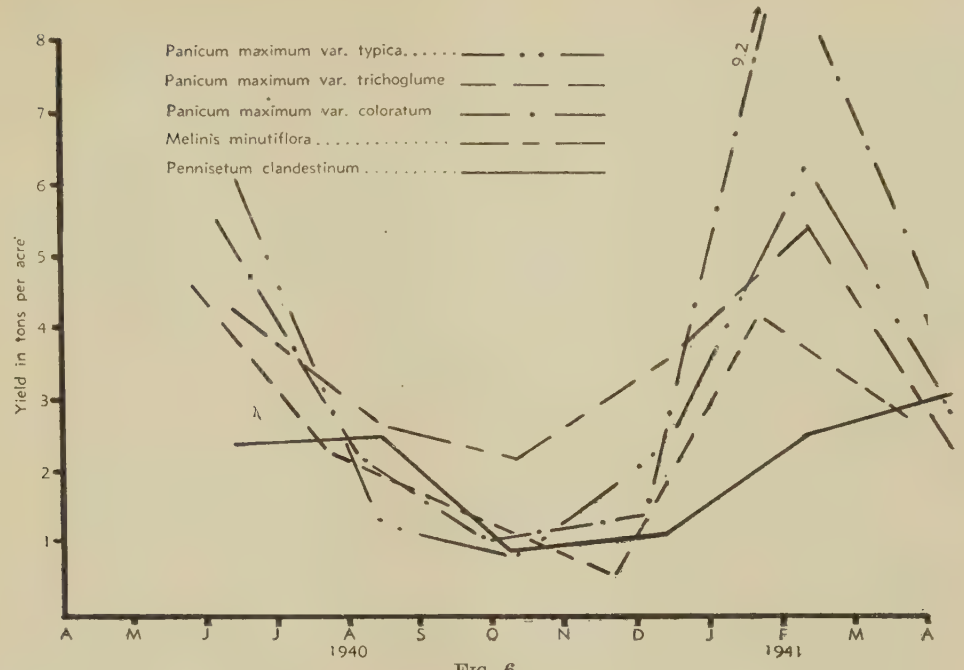

FIG. 6.

Showing Productivity Curves for the First 12 Months of *Melinis minutiflora, Panicum maximum* var. *coloratum, P. maximum* var. *trichoglume, P. maximum* var. *typica* and *Pennisetum clandestinum* cut at Two-monthly Intervals.

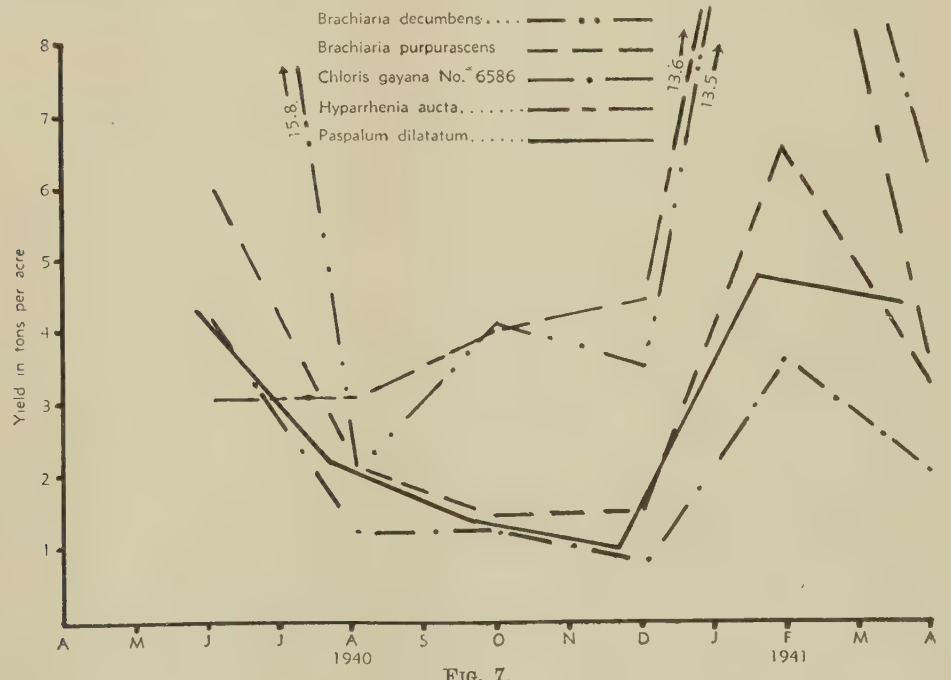

FIG. 7.

Showing Productivity Curves for the First 12 Months of *Brachiaria decumbens, B. purpurascens, Chloris gayana* No. 6586, *Hyparrhenia aucta* and *Paspalum dilatatum* cut at Two-monthly Intervals.

significant. *Brachiaria decumbens* has a significantly higher yield than any of the other grasses. *Panicum maximum* var. *typica* is outyielded by several grasses.

Table 9 shows that six grasses out of ten have given increased yields in the first year under the longer cutting rotation. The largest increase (37 per cent.) is shown by *Brachiaria decumbens*. Reductions in productivity amounting to 17 per cent. and 21 per cent. respectively are shown by *Panicum maximum* var. *typica* and *P. maximum* var. *trichoglume*, while *Melinis minutiflora* and *Pennisetum clandestinum* each yielded approximately the same amount under the two treatments.

Table 12.

TWO-MONTHLY CUT—FIRST 12 MONTHS.

Summary of Results—Green Matter.

Grass.	Mean Yield in Tons per Acre.	Percentage of Mean.	Significance Table.	
			1 per cent. Level.	5 per cent. Level.
1. *Brachiaria decumbens*	45·5	205·9	> Nos. 2–19	..
2. *Hyparrhenia aucta*	31·9	144·3	> Nos. 8–19	> Nos. 7–19
3. *Panicum maximum* No. 1202	30·2	136·6	> Nos. 10–19	> Nos. 8–19
4. *Panicum maximum* No. 3783	27·2	123·1	> Nos. 13–19	> Nos. 11–19
5. *Panicum maximum* No. 3820	26·9	121·7	> Nos. 13–19	> Nos. 11–19
6. *Urochloa bolbodes*	26·7	120·8	ditto	ditto
7. *Panicum maximum* var. *coloratum* ..	24·1	109·0	> Nos. 18 & 19	> Nos. 13–19
8. *Chloris gayana* No. 6585	21·7	98·2	No significant difference	> Nos. 18 & 19
9. *Brachiaria purpurascens*	20·8	94·1	..	> Nos. 18 & 19
10. *Melinis minutiflora*	20·4	92·3	..	ditto
11. *Panicum maximum* var. *typica* ..	19·7	89·1	..	> No. 19
12. *Paspalum dilatatum*	17·8	80·5	..	No significant difference
13. *Cenchrus ciliaris*	16·7	75·6	..	..
14. *Panicum maximum* No. 1200	16·4	74·2	..	..
15. *Cynodon plectostachyum*	16·3	73·7	..	..
16. *Panicum maximum* var. *trichoglume* ..	15·9	71·9	..	..
17. *Digitaria milanjiana*	15·3	69·2	..	..
18. *Chloris gayana* No. 6586	13·0	58·8	..	..
19. *Pennisetum clandestinum*	12·5	56·6	..	..
Mean	22·1	100·0	..	..
S.E.	2·33	10·54	..	..

Standard error of the difference between two means $= 10{\cdot}54\sqrt{2} = 14{\cdot}91$

using the t test, $n = 18$ { 2·101 P = ·05 required difference 31·32; 2·878 P = ·01 42·90

Second 12 Months.—Table 13 gives the individual yield figures for the second 12 months and the results of the analysis of variance of these yields are summarized in Table 14. Varietal effect is highly significant.

Table 13.

SHOWING TWO-MONTHLY PRODUCTIVITY FIGURES OF SELECTED GRASSES FOR SECOND 12 MONTHS IN TONS GREEN MATTER PER ACRE.

Date Cut. Series I.	*Urochloa bolbodes.*	*Panicum maximum* var. *trichoglume.*	*Digitaria milanjiana.*	*Paspalum dilatatum.*
Total 1st 12 months	26·96	15·95	15·31	17·85
20– 5–41	0·96	0·71	1·61	1·61
18– 7–41	0·65	0·40	0·52	0·66
18– 9–41	0·33	0·23	0·04	0·12
17–11–41	1·16	0·92	0·39	0·39
15– 1–42	4·08	2·35	2·21	1·12
17– 3–42	8·14	5·32	11·88	6·81
Total	15·32	9·93	16·65	10·71
Grand Total ..	42·28	25·88	31·96	28·56
Series II.	*Hyparrhenia aucta.*	*Panicum maximum* var. *coloratum.*	*Brachiaria decumbens.*	*Chloris gayana* No. 6586.
Total 1st 12 months	31·88	24·10	45·50	12·96
30– 5–41	0·36	1·22	1·68	0·52
29– 7–41	0·32	0·35	0·53	0·37
26– 9–41	0·33	0·19	0·19	0·30
26–11–41	1·43	2·00	2·15	0·70
28– 1–42	5·16	4·51	6·40	1·35
25– 3–42	8·56	8·39	10·59	3·70
Total	16·16	16·66	21·54	6·94
Grand Total ..	48·04	40·76	67·04	19·90
Series III.	*Pennisetum clandestinum.*	*Panicum maximum* var. *typica.*	*Chloris gayana* No. 6585.	*Melinis minutiflora.*
Total 1st 12 months	12·52	19·69	21·71	20·37
9– 6–41	1·63	0·56	1·50	1·31
8– 8–41	0·20	0·15	0·30	0·27
7–10–41	0·08	0·20	0·16	0·54
5–12–41	0·64	2·18	1·29	2·17
4– 2–42	1·36	7·22	3·77	4·75
6– 4–42	2·51	10·66	4·06	6·39
Total	6·42	20·97	11·08	15·43
Grand Total ..	18·94	40·66	32·79	35·80

As in the second 12 months under a monthly cutting rotation, practically all the grasses yielded lower amounts of green matter under the two-monthly cutting. The exceptions are *Panicum maximum* var. *typica* and *Digitaria milanjiana,* both of which show small increases. The appropriate productivity curves are shown in Figures 8 and 9; these demonstrate the marked effect from

Table 14.

TWO-MONTHLY CUT—SECOND 12 MONTHS.

Summary of Results—Green Matter.

Grass.	Mean Yield in Tons per Acre.	Percentage of Mean.	Significance Table.	
			1 per cent. Level.	5 per cent. Level.
1. *Brachiaria decumbens*	21·5	153·6	> Nos. 3–12	..
2. *Panicum maximum* var. *typica* ..	21·0	150·0	> Nos. 5–12	> Nos. 3–12
3. *Digitaria milanjiana*	16·6	118·6	> Nos. 8–12	..
4. *Panicum maximum* var. *coloratum* ..	16·6	118·6	ditto	..
5. *Hyparrhenia aucta*	16·1	115·0	ditto	..
6. *Melinis minutiflora*	15·4	110·0	> Nos. 10–12	> Nos. 8–12
7. *Urochloa bolbodes*	15·3	109·3	ditto	ditto
8. *Chloris gayana* No. 6585	11·1	79·3	No significant difference	> Nos. 11 & 12
9. *Paspalum dilatatum*	10·7	76·4	..	ditto
10. *Panicum maximum* var. *trichoglume* ..	9·9	70·7	..	> No. 12
11. *Chloris gayana* No. 6586	7·0	50·0	..	No significant difference
12. *Pennisetum clandestinum*	6·4	45·7	..	..
Mean	14·0	100·0	..	..
S.E.	1·11	7·93	..	..

Standard error of the difference between two means $= 7{\cdot}93\sqrt{2} = 11{\cdot}21$

using the t test, $n = 11$ { 2·201 P = ·05 required difference 24·67; 3·106 P = ·01 34·82

November onwards of fertilizer application during the second 12 months. The largest decrease (53 per cent.) occurs with *Brachiaria decumbens*, while decreases of 49 per cent. are shown by *Chloris gayana* No. 6585, *Hyparrhenia aucta* and *Pennisetum clandestinum*. *Panicum maximum* vars. *trichoglume* and *coloratum* show decreases of 38 per cent. and 31 per cent. respectively, and *Melinis minutiflora* shows the smallest decrease (24 per cent.).

The marked reaction of *Panicum maximum* var. *typica* to fertilizer application is again in evidence. During the period December 5, 1941, to April 6, 1942, under a two-monthly cutting rotation this grass produced 44 per cent. of its total yield for a period of 24 months. *Digitaria milanjiana* produced 44 per cent. of its total yield from November 17, 1941, to March 17, 1942. It can be stated, therefore, that *Panicum maximum* var. *typica* under both monthly and two-monthly cutting rotations, and *Digitaria milanjiana* under a two-monthly cutting rotation, reacted strongly to fertilizer (consisting of blood and superphosphate) applied immediately after each cut had been harvested during the second 12 months. The total amount of fertilizer added to the *Panicum maximum* var. *typica* plots was equivalent to 12 cwt. blood and 3.8 cwt. superphosphate per acre for the plots cut monthly, and 8·8 cwt. blood and 2 cwt. superphosphate for the plots cut at two-monthly intervals. The plots of *Digitaria*

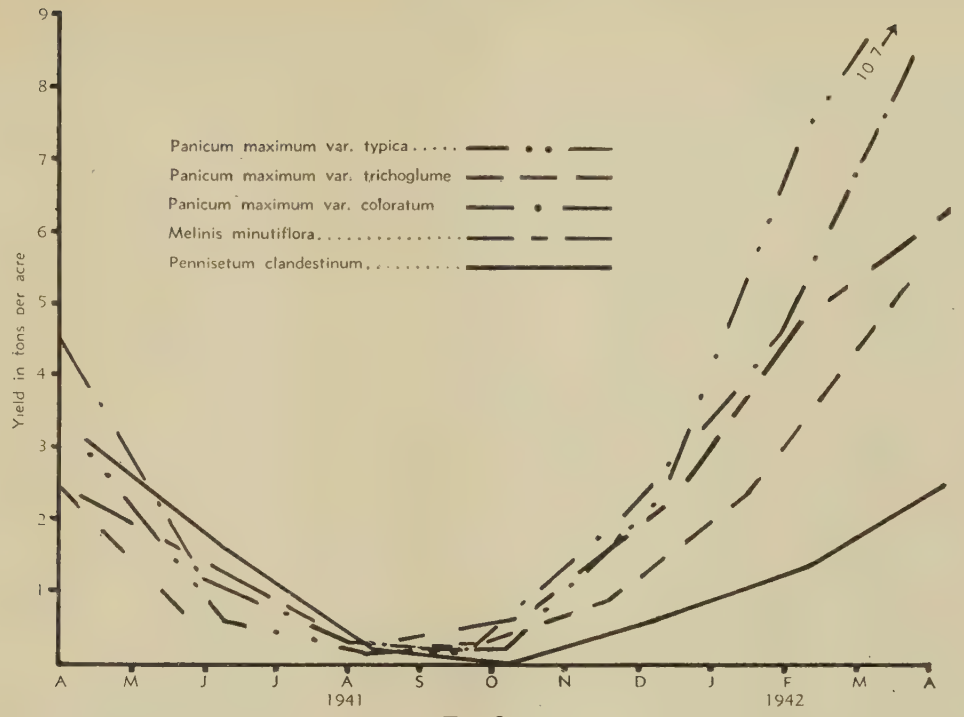

FIG. 8.

Showing Productivity Curves for the Second 12 Months of *Melinis minutiflora*, *Panicum maximum* var. *coloratum*, *P. maximum* var. *trichoglume*, *P. maximum* var. *typica* and *Pennisetum clandestinum* cut at Two-monthly Intervals.

milanjiana cut every two months received a total amount equivalent to 8 cwt. per acre of blood and 1·9 cwt. per acre of superphosphate.

Two-year Period.—Yield figures for the whole period of two years under a two-monthly cutting rotation have been treated by the analysis of variance method and the results are summarized in Table 15. Varietal effect is highly significant.

The highest yielding grass is *Brachiaria decumbens* at 67 tons green matter per acre. The next four grasses are *Hyparrhenia aucta*, *Urochloa bolbodes*, *Panicum maximum* var. *coloratum* and *P. maximum* var. *typica*, all of which produce 40-50 tons per acre. They are significantly higher in yield at the 1 per cent. level than the four lowest yielding grasses—*Paspalum dilatatum*, *Panicum maximum* var. *trichoglume*, *Chloris gayana* No. 6586 and *Pennisetum clandestinum*, which range from 28 to 19 tons per acre.

Three-monthly Cuts.

The individual yields in tons per acre green matter of the various grasses at each harvest under a system of three-monthly cutting are given in Table 16. The corresponding productivity curves are shown in Figures 10 and 11.

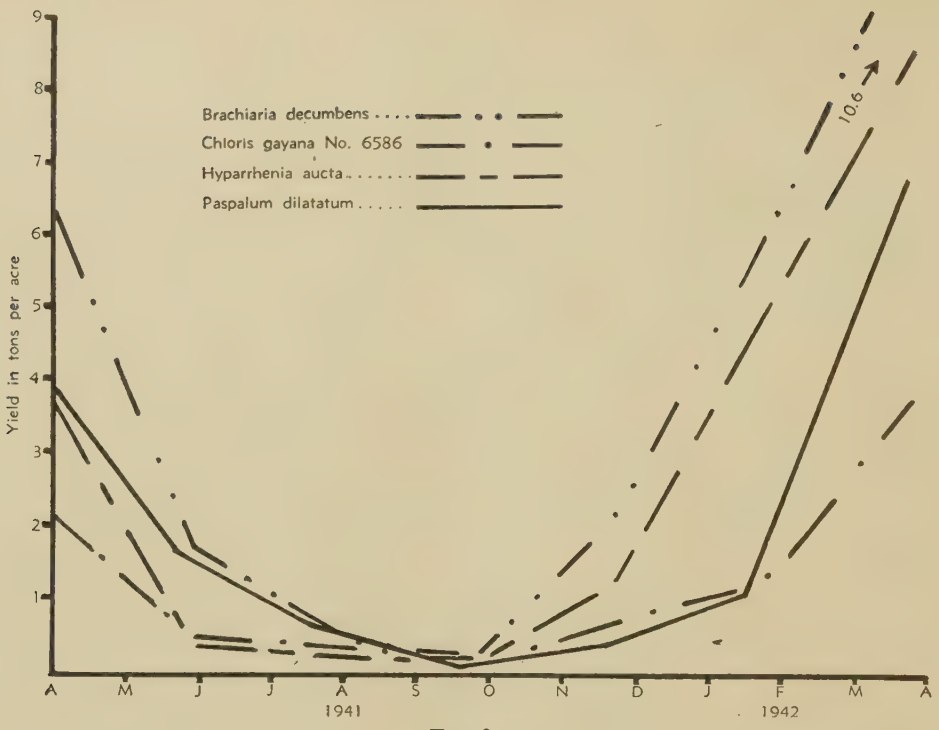

FIG. 9.

Showing Productivity Curves for the Second 12 Months of *Brachiaria decumbens*, *Chloris gayana* No. 6586, *Hyparrhenia aucta* and *Paspalum dilatatum* cut at Two-monthly Intervals.

The information which can be obtained from a study of the productivity curves is restricted by the fact that each grass was cut four times only during the year. However, all the grasses with the exception of *Hyparrhenia aucta*—which will be discussed later—show a marked decrease in yield from the first cut (June 5—July 15) to the second cut (September 23—October 11). The third cut (December 20—January 10) reveals interesting variations in response between some of the grasses. Thus *Panicum maximum* var. *trichoglume*, and *Pennisetum clandestinum* (Figure 10), and *Paspalum dilatatum*, *Chloris gayana* No. 6586 and *Brachiaria purpurascens* (Figure 11) demonstrate a continuation of this low productivity to the third cut, but at the fourth cut, from March 21—April 10, there is a considerable increase of yield. *Panicum maximum* var. *coloratum* occupies an intermediate position, as it reaches a low productivity of 1.34 tons with the cut taken October 1; by December 31 the yield has increased to 3.45 tons, and in the final cut on April 1 it reaches 7.77 tons. *Panicum maximum* var. *typica* and *Melinis minutiflora* by contrast show their peak yields in the first cut after establishment; this is followed by a marked reduction at the second cut, a rapid increase to the third cut, and a slight diminution in productivity at the fourth cut. *Brachiaria decumbens* also reaches its peak yield at the first cut, after which a considerable fall occurs, equivalent

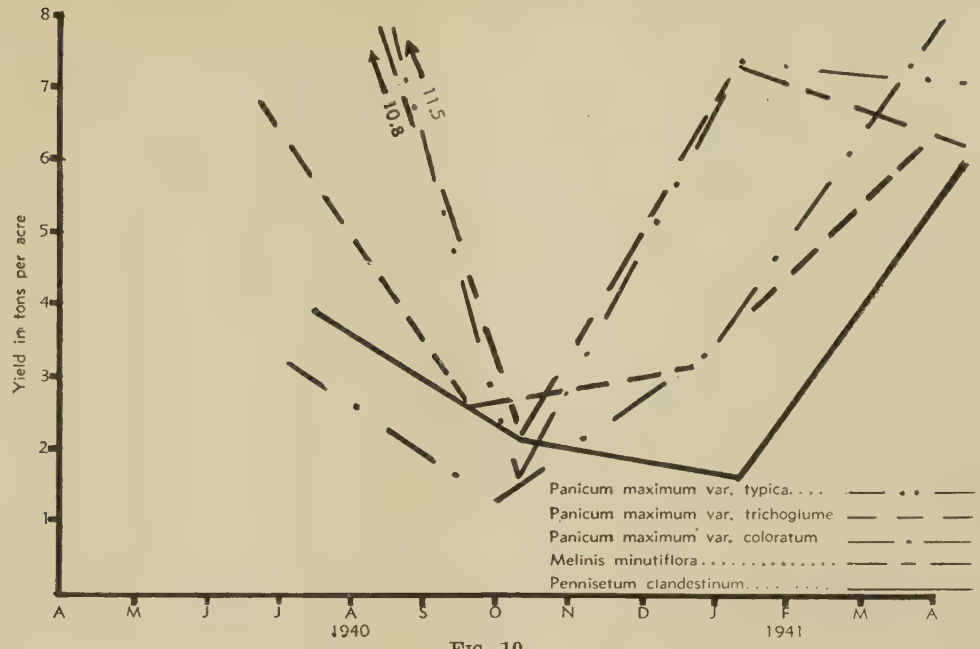

FIG. 10.

Showing Productivity Curves for the First 12 Months of *Melinis minutiflora, Panicum maximum* var. *coloratum, P. maximum* var. *trichoglume, P. maximum* var. *typica* and *Pennisetum clandestinum* cut at Three-monthly Intervals.

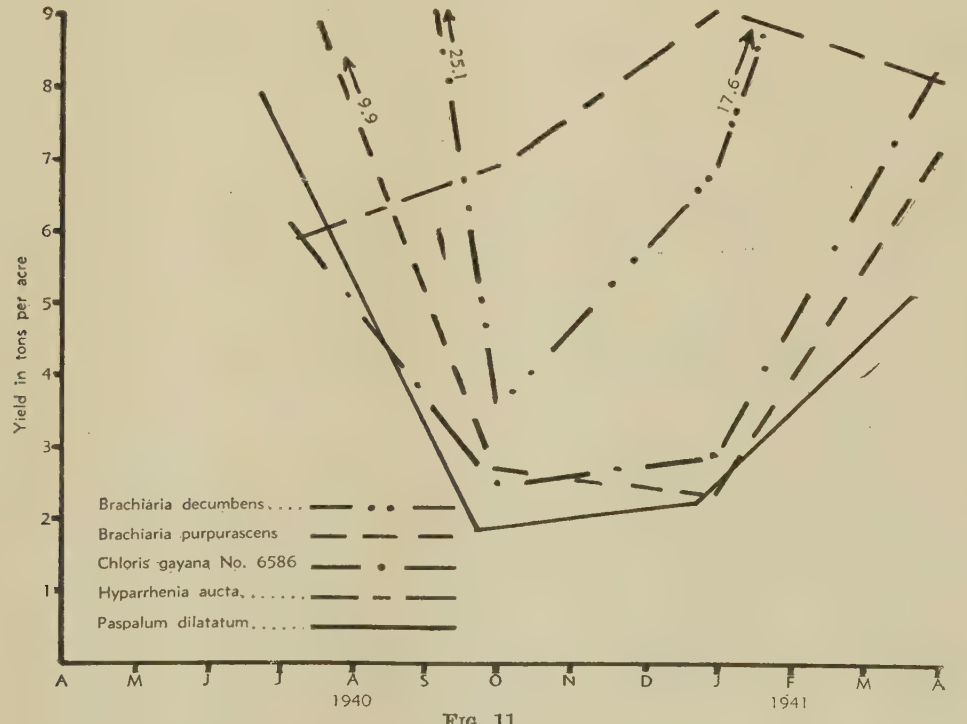

FIG. 11.

Showing Productivity Curves for the First 12 Months of *Brachiaria decumbens, B. purpurascens, Chloris gayana* No. 6586, *Hyparrhenia aucta* and *Paspalum dilatatum* cut at Three-monthly Intervals.

Table 15.

TWO-MONTHLY CUT OVER TWO YEARS.

Summary of Results—Green Matter.

Grass.	Mean Yield in Tons per Acre.	Percentage of Mean	Significance Table.	
			1 per cent. Level.	5 per cent. Level.
1. *Brachiaria decumbens*	67·0	186·1	> Nos. 2–12	..
2. *Hyparrhenia aucta*	48·0	133·3	> Nos. 6–12	> Nos. 3–12
3. *Urochloa bolbodes*..	42·1	116·9	> Nos. 9–12	> Nos. 7–12
4. *Panicum maximum* var. *coloratum* ..	40·7	113·0	> Nos. 9–12	> Nos. 7–12
5. *Panicum maximum* var. *typica* ..	40·6	112·8	ditto	ditto
6. *Melinis minutiflora*	35·8	99·4	> Nos. 11–12	> Nos. 10–12
7. *Chloris gayana* No 6585	32·8	91·1	> Nos. 11 & 12	> Nos. 11–12
9. *Digitaria milanjiana*	32·0	88·9	ditto	ditto
9. *Paspalum dilatatum*	28·5	79·2	No significant difference	Nos. 11–12
10. *Panicum maximum* var. *trichoglume* ..	25·9	71·9	..	No significant difference
11. *Chloris gayana* No. 6586	19·9	55·3	..	..
12. *Pennisetum clandestinum*	18·9	52·5	..	..
Mean	36·0	100·0	..	..
S.E.	2·55	7·08	..	..

Standard error of the difference between two means $= 7{\cdot}08\sqrt{2} = 10{\cdot}01$

using the t test, $n = 11$ { 2·201 P = ·05 required difference 22·03; 3·106 P = ·01 31·09

to 40.5 per cent. of the total yield; productivity is nearly doubled at the next cut, and there is a marked increase in yield at the fourth cut. *Hyparrhenia aucta* shows exceptional behaviour throughout, in that a steady increase in yield occurs from the first to the third cut, when the peak yield of 9.08 tons is obtained, which falls to 8.07 tons at the fourth cut on April 1.

The yield totals given in Table 16 have been subjected to the analysis of variance and the results are summarized in Table 17. Varietal effect is highly significant.

The most outstanding point arising from these results is the general increase in yield shown by the majority of the grasses over the monthly and two-monthly cutting rotation figures. Four grasses only—*Panicum maximum* vars. *coloratum* and *trichoglume* and No. 1200, and *Cenchrus ciliaris*—show reductions in yield compared with monthly cutting, and these are all small. *Panicum maximum* var. *coloratum* and No. 1200, *Cenchrus ciliaris* and *Chloris gayana* No. 6585 yield less under three-monthly cutting than under two-monthly cutting. It is of interest to note that, while *Panicum maximum* var. *coloratum* gave an increase in yield of 29 per cent. from two-monthly cutting over monthly cutting, this grass showed a considerable decrease in yield under three-monthly cutting. In general,

however, the longer cutting rotation tended to increase yields during the first 12 months. Compared with monthly cutting, three-monthly cutting has shown the following substantial increases in yield: *Brachiaria decumbens*, 59 per cent.; *Chloris gayana* No. 6586, 53 per cent.; *Melinis minutiflora*, 30 per cent.; and *Brachiaria purpurascens*, 28 per cent. A comparison of dry matter yields (see Tables 22-24) serves to emphasize still further the higher rate of productivity resulting from the longer cutting rotations. This is in agreement with the results obtained by many other workers (Davies and Sim, 1931; Paterson, 1935; Richardson, 1932; Richardson, Trumble and Shapter, 1932; and Stapledon, 1924).

VARIATION IN YIELD IN THE DIFFERENT PRODUCTIVITY PERIODS UNDER A SYSTEM OF MONTHLY CUTTING.

Table 2 shows that the number of days contributing to the different productivity phases varies considerably. Thus in series I. the "low" period

Table 16.

SHOWING THREE-MONTHLY PRODUCTIVITY FIGURES OF VARIOUS GRASSES FOR 12 MONTHS IN TONS GREEN MATTER PER ACRE.

Series I. Date Cut.	*Urochloa bolbodes.*	*Panicum maximum* var. *trichoglume.*	*Panicum maximum* No. 1202.	*Panicum maximum* No. 3783.	*Digitaria milanjiana.*	*Paspalum dilatatum.*	*Cenchrus ciliaris.*
25– 6–40 ..	8·47	6·72	7·99	11·60	5·75	7·89	6·14
23– 9–40 ..	2·10	2·58	2·84	2·95	1·52	1·77	0·96
20–12–40 ..	5·99	3·24	6·16	5·42	2·64	2·20	1·84
21– 3–41 ..	10·03	6·08	18·95	11·11	11·79	5·05	5·37
Total ..	26·59	18·62	35·94	31·08	21·70	16·91	14·31

Series II. Date Cut.	*Hyparrhenia aucta.*	*Cynodon plectostachyum.*	*Panicum maximum* var. *coloratum.*	*Panicum maximum* No. 1200.	*Brachiaria purpurascens.*	*Brachiaria decumbens.*	*Chloris gayana* No. 6586.
5– 7–40 ..	5·91	4·76	3·21	5·73	9·91	25·10	6·09
1–10–40 ..	6·90	2·40	1·34	1·28	2·66	3·59	2·45
31–12–40 ..	9·08	2·70	3·45	2·65	2·42	6·85	2·93
1– 4–41 ..	8·07	10·28	7·77	3·97	7·09	17·59	8·26
Total ..	29·96	20·14	15·77	13·63	22·08	53·13	19·73

Series III. Date Cut.	*Pennisetum clandestinum.*	*Panicum maximum* var. *typica.*	*Panicum maximum* No. 3820.	*Chloris gayana* No. 6585.	*Melinis minutiflora.*
15– 7–40 ..	3·93	11·45	9·75	5·74	10·76
11–10–40 ..	2·16	1·64	2·16	2·06	2·25
10– 1–41 ..	1·60	7·41	7·09	3·74	7·38
10– 4–41 ..	5·96	7·06	8·80	6·15	6·18
Total ..	13·65	27·56	27·80	17·69	26·57

extends over 118 days, whereas the number of days in the "rapid increase" period is only 58. If, however, the yield in each productivity phase is expressed as the mean daily yield in pounds of green matter per acre over a period of two years—designated for convenience by the symbol m.d.y.—then a figure is obtained which takes into account the number of days contributing to yield in each period and enables comparisons to be made of the actual variations in productivity which occur with the individual grasses.

Table 17.

THREE-MONTHLY CUT—FIRST 12 MONTHS.

Summary of Results—Green Matter.

Grass.	Mean Yield in Tons. per Acre.	Percentage of Mean.	Significance Table.	
			1 per cent. Level.	5 per cent. Level.
1. *Brachiaria decumbens*	53·1	223·1	> Nos. 3–19	> Nos. 2–19
2. *Panicum maximum* No. 1202	35·9	150·8	> Nos. 14–19	> Nos. 9–19
3. *Panicum maximum* No. 3783	31·1	130·7	No significant difference	> Nos. 14–19
4. *Hyparrhenia aucta*	30·0	126·0	..	> Nos. 15–19
5. *Panicum maximum* No. 3820	27·8	116·8	..	> Nos. 17–19
6. *Panicum maximum* var. *typica* ..	27·5	115·5	..	ditto
7. *Urochloa bolbodes*	26·6	111·8	..	No significant difference
8. *Melinis minutiflora*	26·5	111·3	..	..
9. *Brachiaria purpurascens*	22·1	92·9	..	..
10. *Digitaria milanjiana*	21·7	91·2	..	..
11. *Cynodon plectostachyum*	20·1	84·4	..	..
12. *Chloris gayana* No. 6586	19·7	82·8	..	..
13. *Panicum maximum* var. *trichoglume* ..	18·6	78·1	..	..
14. *Chloris gayana* No. 6585	17·7	74·4	..	..
15. *Paspalum dilatatum*	16·9	71·0	..	..
16. *Panicum maximum* var. *coloratum* ..	15·8	66·4	..	..
17. *Cenchrus ciliaris*	14·3	60·1	..	..
18. *Panicum maximum* No. 1200	13·6	57·1	..	..
19. *Pennisetum clandestinum*	13·6	57·1	..	..
Mean	23·8	100·0	..	..
S.E.	4·39	18·44	..	..

Standard error of the difference between two means $= 18{\cdot}44\sqrt{2} = 26{\cdot}08$

using the t test, $n = 18$ { 2·101 P = ·05 required difference 54·79; 2·878 P = ·01 75·06

First 12 Months.

In the first 12 months after establishment, the range of variation under monthly cutting is comparatively small (Tables 18-20). *Pennisetum clandestinum* during the "low" period has an m.d.y. of 57 lb., which rises during the "zenith" period to 107 lb.; that is, the rate of productivity is practically doubled. *Panicum maximum* var. *trichoglume* has an m.d.y. of 51 lb. in the "low" period and one of 154 lb. in the "zenith" period, an

Table 18.

SHOWING THE VARIATION IN THE DIFFERENT PRODUCTIVITY PERIODS OF MEAN DAILY YIELD OF INDIVIDUAL GRASSES UNDER A MONTHLY CUTTING ROTATION OVER A PERIOD OF TWENTY-FOUR MONTHS (YIELD EXPRESSED AS POUNDS OF GREEN MATTER PER ACRE).

Date of Cut.	Number Days Growth.	Series.	Period.	*Panicum maximum* var. *trichoglume.*	*Paspalum dilatatum.*
25– 6–40	89	I	After establishment	223	133
22–10–40	118	I	Low	51	40
20–12–40	58	I	Rapid increase ..	96	64
21– 3–41 (1st 12 months.)	90	I	Zenith	154	120
20– 6–41	90	I	Rapid decrease ..	41	46
17–10–41	118	I	Low	14	4
16–12–41	59	I	Rapid increase ..	130	43
17– 3–42 (2nd 12 months.)	90	I	Zenith	199	147
Total ..	712				

				Hyparrhenia aucta.	*Panicum maximum* var. *coloratum.*	*Brachiaria purpurascens.*	*Brachiaria decumbens.*	*Chloris gayana* No. 6586.
5– 7–40	91	II	After establishment	94	146	215	318	128
1–11–40	118	II	Low	143	34	34	99	40
31–12–40	60	II	Rapid increase ..	214	136	59	173	57
1– 4–41 (1st 12 months.)	90	II	Zenith	278	182	130	263	100
30– 6–41	89	II	Rapid decrease ..	25	28	..	57	20
27–10–41	118	II	Low	22	6	..	11	11
29–12–41	62	II	Rapid increase ..	168	104	..	152	40
25– 3–42 (2nd 12 months.)	85	II	Zenith	299	254	..	310	53
Total ..	713							

				Pennisetum clandestinum.	*Panicum maximum* var. *typica.*	*Melinis minutiflora.*
15– 7–40	90	III	After establishment	99	196	102
11–11–40	118	III	Low	57	43	119
10– 1–41	59	III	Rapid increase ..	64	189	189
10– 4–41 (1st 12 months.)	89	III	Zenith	107	215	131
10– 7–41	90	III	Rapid decrease ..	35	32	50
6–11–41	118	III	Low	3	15	22
7– 1–42	61	III	Rapid increase ..	47	225	138
6– 4–42 (2nd 12 months.)	87	III	Zenith	101	422	228
Total ..	712					

increase in productivity of 200 per cent. *Melinis minutiflora* during the period after establishment has an m.d.y. of 119 lb., which rises to 131 lb. during the "zenith" period, an increase of only 10 per cent., although an m.d.y. of 189 lb.

was recorded during the "rapid increase" period, thus showing a different behaviour from that of the other grasses with the exception of *Hyparrhenia aucta*. The largest variation in productivity is given by *Panicum maximum* var. *coloratum*, which shows an increase in productivity of 435 per cent. during the "zenith" period (m.d.y. 182 lb.) as compared with the "low" period (m.d.y. 34 lb.).

Second 12 Months.

It is not until after the first year that any considerable variation in productivity occurs. During the first year the effect of the basal fertilizer dressing combined with the upward trend of productivity during the "rapid increase" and "zenith" periods has served to keep up productivity. In the second year, however, apart from the meteorological conditions, two factors have a marked effect on productivity. The first results from the continued removal of the cut herbage after each cut and causes a marked lowering of yield during the "rapid decrease" and "low" periods. The second follows the application of fertilizer in the second year and becomes effective in the "rapid increase" and "zenith" periods. Productivity in the second twelve months, therefore, offers an interesting comparison of the depressing effect of continued harvesting without fertilizer application (apart from the basal dressing) operative over the "rapid decrease" and "low" periods, as against the stimulating action of fertilizer applied at monthly intervals during the second twelve months, which makes its effect felt over the "rapid increase" and "zenith" periods of productivity.

The greatest variation occurs with *Panicum maximum* var. *coloratum*, which has an m.d.y. of 6 lb. only in the "low" period, and an m.d.y. of 254 lb. in the "zenith" period, equivalent to an increase of productivity of 41 times. *Paspalum dilatatum* gives an increase of 36, *Panicum maximum* var. *typica* 27, *Brachiaria decumbens* 27, *Panicum maximum* var. *trichoglume* and *Hyparrhenia aucta* 13, *Melinis minutiflora* 9 and *Chloris gayana* No. 6586, 4 times the productivity in the "zenith" compared with the "low" period.

Table 19.

Showing the Mean Daily Yield Figures in the "Low" Period of Productivity in the First and Second 12 Months under a Monthly Cutting Rotation and the Corresponding Percentage Decrease in Yield.

Grass.	Mean Daily Yield First 12 Months.	Mean Daily Yield Second 12 Months.	Percentage Decrease in Productivity.
	Lb.	Lb.	
Panicum maximum var. *trichoglume*	51	14	72
Paspalum dilatatum	40	4	90
Hyparrhenia aucta	143	22	85
Panicum maximum var. *coloratum*	34	6	82
Brachiaria decumbens	99	11	89
Chloris gayana No. 6586	40	11	72
Pennisetum clandestinum	57	3	95
Panicum maximum var. *typica*	43	15	65
Melinis minutiflora	119	22	81

Comparison of First and Second 12 Months.

(*a*) *"Low" Period.*—A comparison of the m.d.y. figures for the "low" period of productivity during the first and second 12 months is of interest, as it illustrates the considerable decrease in yield caused by the continued removal of herbage before the fertilizer application added in the second 12 months has had time to become effective (see Table 19).

The largest decrease in yield (95 per cent.) occurs with *Pennisetum clandestinum,* and the smallest (65 per cent.), with *Panicum maximum* var. *typica.* It is evident that with *Pennisetum clandestinum* there is a marked limiting effect operating caused by one or more factors, one of which is undoubtedly shortage of nitrogen aggravated by the absence of the grazing factor.

(*b*) *"Zenith" Period.*—The m.d.y. figures shown in Table 20 indicate the extent of the variation in yield which occurs in the "zenith" period of the second 12 months compared with the same period in the first year.

Table 20.

SHOWING THE MEAN DAILY YIELD FIGURES IN THE "ZENITH" PERIOD OF PRODUCTIVITY IN THE FIRST AND SECOND 12 MONTHS UNDER A MONTHLY CUTTING ROTATION AND THE CORRESPONDING PERCENTAGE DIFFERENCE IN YIELD.

Grass.	Mean Daily Yield First 12 Months.	Mean Daily Yield Second 12 Months.	Percentage Difference in Productivity.
	Lb.	Lb.	
Panicum maximum var. *trichoglume*	154	199	+29
Paspalum dilatatum	120	147	+22
Hyparrhenia aucta	278	299	+ 7
Panicum maximum var. *coloratum*	182	254	+40
Brachiaria decumbens	263	310	+18
Chloris gayana No. 6586	100	53	−47
Pennisetum clandestinum	107	101	− 6
Panicum maximum var. *typica*	215	422	+96
Melinis minutiflora	131	228	+74

The percentage increases in yield shown in this table demonstrate the great variations which occur at the "zenith" period between the different grasses in their reaction to the application of fertilizer in the second 12 months under a monthly system of cutting. *Panicum maximum* var *typica* is outstanding, showing an increase of 96 per cent. in the second year "zenith" period compared with the first 12 months. The increase of 74 per cent. by *Melinis minutiflora* is rather complicated by its behaviour during the first 12 months, when it showed an m.d.y. of 189 lb. in the "rapid increase" period but 131 lb. only in the "zenith" period. *Panicum maximum* vars. *coloratum* and *trichoglume* and *Paspalum dilatatum* show increases of 40 per cent., 29 per cent. and 22 per cent. respectively, indicating the great difference in yield response between *P. maximum* var. *typica* and the other Guinea grass varieties. *Brachiaria decumbens* and *Hyparrhenia aucta,* with increases of 18 per cent. and 7 per cent. respectively,

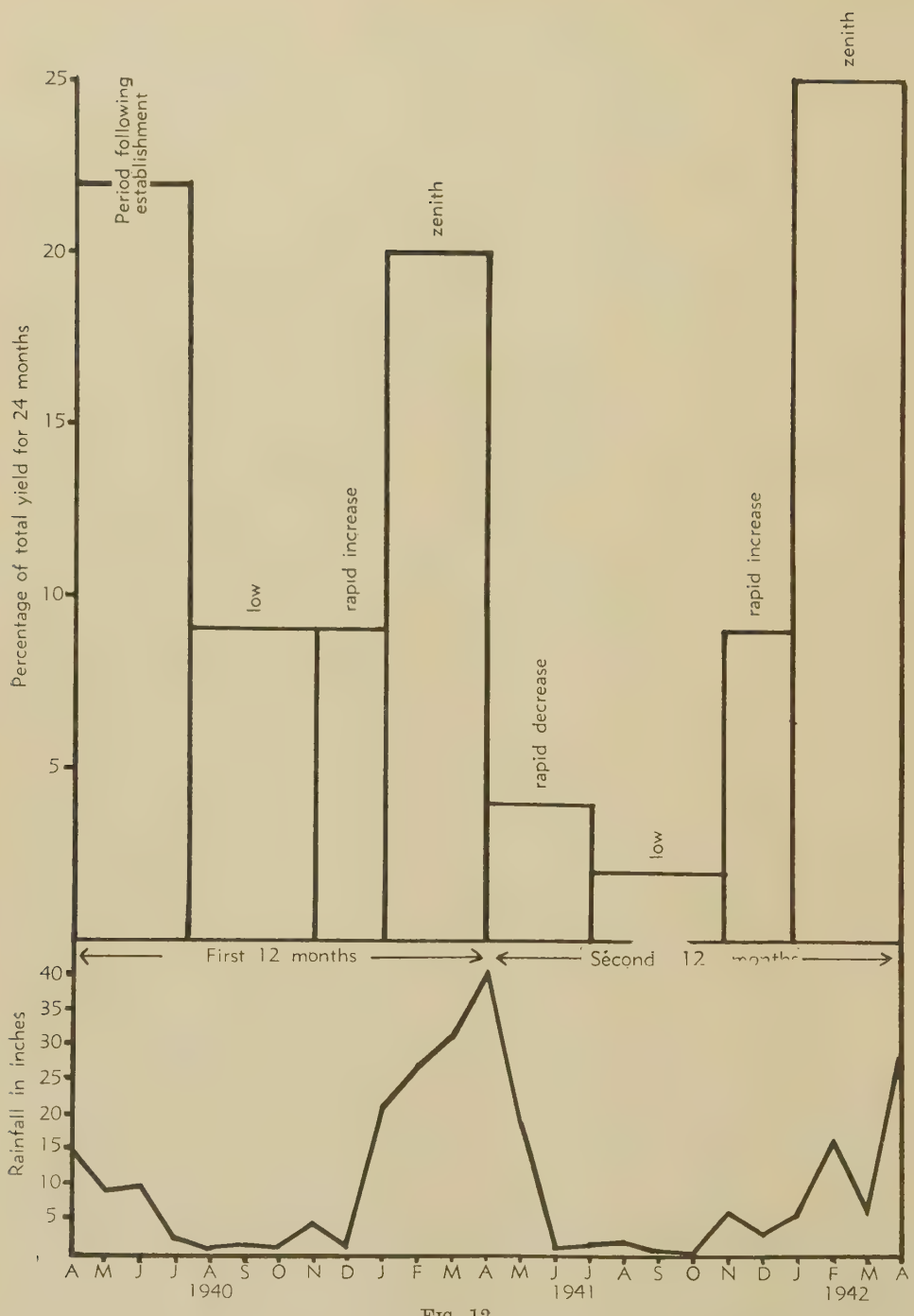

FIG. 12.

Showing Mean Yield in Various Productivity Periods of Seven Grasses cut at Monthly Intervals Over a Period of Two Years and Rainfall During that Period.

show little change. *Pennisetum clandestinum* gives a decrease of 6 per cent. and *Chloris gayana* No. 6586 shows its unsuitability for growth in the wet zone by a reduction in yield of 47 per cent.

General Pattern of Productivity.

The productivity curves of a number of selected grasses under different cutting rotations have been examined. It now remains to consider the mean productivities and mean daily yields, excluding the two exceptions *Hyparrhenia aucta* and *Melinis minutiflora*, to determine the general pattern of productivity during the first and second 12 months under a monthly system of cutting. Table 21 shows the mean productivity and mean yield expressed as a percentage of

Table 21.

SHOWING MEAN PRODUCTIVITY AND MEAN DAILY YIELD CALCULATED FOR THE SEVEN GRASSES: *Panicum maximum* vars. *trichoglume, coloratum* and *typica, Paspalum dilatatum, Pennisetum clandestinum, Brachiaria decumbens* AND *Chloris gayana* No. 6586 GROUPED INTO PRODUCTIVITY PERIODS UNDER A SYSTEM OF MONTHLY CUTS.

Period of Growth inclusive of Series I, II, and III.	27/3/40 15/7/40 Period after Establishment.	25/ 6/40 11/11/40 Low.	22/10/40 10/ 1/41 Rapid Increase.	20/12/40 10/ 4/41 Zenith.	21/3/41 10/ 7/41 Rapid Decrease.	20/ 6/41 6/11/41 Low.	17/10/41 7/ 1/42 Rapid Increase.	16/12/41 6/ 4/42 Zenith.
Percentage contribution to total production over a period of 24 months	22	9	9	20	4	2	9	25
Mean daily yield expressed in pounds green matter over a period of 24 months	178	52	111	163	37	9	106	212

the mean daily yield over a period of 24 months, and these results are given in the form of histograms is Figures 12 and 13 for the seven grasses: *Panicum maximum* vars. *trichoglume, coloratum* and *typica, Paspalum dilatatum, Pennisetum clandestinum, Brachiaria decumbens* and *Chloris gayana* No. 6586.

A study of the productivity curves shown in Figures 2, 3, 4, and 5—with the exception of the two grasses *Hyparrhenia aucta* and *Melinis minutiflora*—and the histograms in Figures 12 and 13 enables the following conclusions to be made:—

(1) There is a phase of high productivity immediately following the period of establishment, when this period occurs immediately before or at the commencement of the wet season.

FIG. 13.

Showing the Mean Daily Yield in Various Productivity Periods of Seven Grasses cut at Monthly Intervals Over a Period of Two Years and Average Temperatures During that Period.

(2) The division of each 12 months into four well-defined periods of productivity: "rapid decrease," "low," "rapid increase," and "zenith," described previously, is clearly demonstrated.

(3) There appears to be a positive correlation between yield and rainfall, temperature and length of day.

(4) A marked falling-off in yield is noticeable during the second period of 12 months from April to the end of October, in spite of a monthly application of superphosphate and blood (calculated on 1/12th of the nutrients removed in the herbage during the first 12 months) added to the plots after each cut over the second year.

(5) A rapid increase of yield occurs from November onwards during the second 12 months as a result of fertilizer application becoming effective (see Figures 4, 5, 8 and 9). During the dry winter period fertilizer showed no effect, but with the increase of temperature and rainfall during the spring and summer a marked uplift in yield is obtained, which is in accordance with expectation.

Exceptions to the General Pattern of Productivity.

It is clear from Tables 2 and 21 that two grasses—*Hyparrhenia aucta* and *Melinis minutiflora*—show unusual behaviour when subjected to monthly cutting. The reaction of the latter grass, however, is quite different to that of *Hyparrhenia aucta*. The productivity figures for molasses grass indicate that monthly cutting in the first 12 months has merely upset the normal growth rhythm, as is shown by its regular development during the second 12 months under monthly cutting, throughout 24 months of two-monthly cutting and during 12 months under a three-monthly cutting rotation. In short, molasses grass possesses the same type of functional periodicity as the majority of the grasses examined. *Hyparrhenia aucta*, by contrast, shows that it possesses a different growth periodicity from all the other grasses under each cutting treatment.

Under a monthly cutting rotation, *Hyparrhenia aucta* in the period following establishment—when most of the other grasses produced 20 per cent. or more of their total yield for 24 months—gave 8 per cent. only, with an m.d.y. of 94 lb. (see Tables 2 and 18.) These figures are easily the lowest in the group of grasses examined, with the exception of *Melinis minutiflora*. In the "low" period 16 per cent. of the total yield is produced and the m.d.y. is 143 lb. Actually, therefore, an increase in yield of 8 per cent. has occurred over the previous period whereas all the other grasses—except *Melinis minutiflora*—show decreases (see Figure 3). During the "rapid increase" and "zenith" periods of the first 12 months *Hyparrhenia aucta* follows the normal growth pattern, but in the "low" period of the second 12 months its behaviour is again abnormal, as it produces an increase of 1 per cent. of its total yield over the previous "rapid decrease" period when all the other grasses show decreases. *H. aucta* is again abnormal under a two-monthly cutting rotation

in that no "low" period of productivity comparable with the other grasses is shown during the first 12 months (see Figure 7). In the second 12 months the productivity of *H. aucta* remains practically constant from 30-5-41 to 26-9-41, yet all the remaining grasses show very marked decreases in yield (see Table 13 and Figure 5). Under a three-monthly cutting rotation also *H. aucta* shows no "low" period of productivity (see Figure 11).

These results are important because they demonstrate that, even under the rather extreme meteorological conditions of the Innisfail area, it is possible for a grass to show *exceptional* behaviour to the normal growth rhythm exhibited by the majority of grasses examined. In this connexion the fact that *Hyparrhenia aucta* is very similar to some of the *native Andropogoneae* should not be overlooked. The collection of evidence to show that certain grasses do possess a different growth rhythm under the Innisfail type of climate was in fact one of the objects of this experiment, and it explains why an unpalatable, harsh grass such as *H. aucta* was included. Observation in the field had shown that the grass possessed a different growth rhythm and it was considered advisable to obtain exact quantitative data on the magnitude of this difference.

Information which deals with differences in productivity as between introduced and native species, especially in respect of early maturing types of herbage, or herbage which yields well over a difficult portion of the year, is a most important factor contributing to the efficient management of grassland, and to the composition of seed mixtures which aim at the production of nutritious herbage throughout the year. Therefore, the evidence presented of the abnormal behaviour of *H. aucta* is significant. For although the grass is harsh and unpalatable, and is actually an introduction, it is nevertheless a member of an important tribe of grasses, the *Andropogoneae,* which includes a number of native species. It is not suggested that some members of the native *Andropogoneae* will also show deviations from the general pattern of productivity, but it is a matter which deserves investigation, especially in the lower-rainfall areas of Queensland. The fact that as the rainfall decreases so does the possibility of effectively using introduced plants diminish and the importance of the native herbage species increase requires constant attention in the search for satisfactory herbage plants.

Variations in Dry-matter Content as Influenced by Season and Frequency of Cutting.

Monthly Cuts.

The degree of variation in dry-matter content is of importance from the point of view of intake of nutrients by grazing stock at various times of the year. Table 5 gives the moisture-free and air-dried figures for various grasses under a monthly cutting rotation during the first 12 months. The dry-matter percentages reveal a marked seasonal fluctuation; further examination of this feature is facilitated by the selection of ten grasses for closer study. The dry-matter percentages of these ten grasses are given in Table 22,

together with data on mean dry-matter percentage and mean yield of green matter in tons per acre per harvest, and the mean daily rainfall figures in inches for the various harvesting periods covering all series. The fact that each harvesting period includes three cutting dates spaced approximately ten days apart, corresponding to each series, tends to make the means less sharply defined than if each series had been taken separately. Nevertheless, these figures are representative of the general trend of dry-matter variation.

Table 22.

SHOWING DRY-MATTER PERCENTAGES—MONTHLY CUTS.

Date of Cut.	*Panicum maximum* var. *trichoglume.*	*Paspalum dilatatum.*	*Hyparrhenia aucta.*	*Panicum maximum* var. *coloratum.*	*Brachiaria purpurascens.*	*Brachiaria decumbens.*	*Chloris gayana* No. 6586.	*Pennisetum clandestinum.*	*Panicum maximum* var. *typica.*	*Melinis minutiflora.*	Mean Dry-matter.	Mean Daily Rainfall in Inches.	Mean Yield of all Grasses per Cut in Tons Green Matter Per Acre.
26- 4- 40 ..	17·8	20·6	..	..	..	..	..	..	..	..	..	..	..
6- 5-40	..	..	21·6	19·9	19·3	20·6	18·8	..	..	..	20·3	0·57	2·64
16- 5-40	..	..	..	..	..	..	..	21·3	20·3	23·1	..	..	..
28- 5-40	18·4	19·5	..	..	..	..	..	..	..	..	..	..	..
5- 6-40	..	..	19·5	21·1	26·6	21·9	21·1	..	..	..	21·1	0·32	2·11
14- 6-40	..	..	..	..	..	..	..	19·9	21·1	21·5	..	..	..
25- 6-40	15·6	19·9	..	..	..	..	..	..	..	..	..	..	..
5- 7-40	..	..	19·5	25·0	19·1	18·8	26·6	..	..	..	22·4	0·26	1·91
15- 7-40	..	..	..	..	..	..	..	24·2	29·3	25·8	..	..	..
22-10-40	32·8	36·4	..	..	..	..	..	..	..	..	..	..	..
1-11-40	..	..	27·2	35·6	31·8	33·8	36·2	..	..	..	34·2	0·06	0·75
11-11-40	..	..	..	..	..	..	..	37·4	39·2	31·4	..	..	..
19- 2-41	19·9	22·7	..	..	..	..	..	..	..	..	..	..	..
30- 1-41	..	..	16·8	15·5	17·2	16·4	18·7	..	..	..	18·9	0·40	3·30
10- 2-41	..	..	..	..	..	..	..	17·6	22·3	21·6	..	..	..
21- 4-41	18·0	14·1	..	..	..	..	..	..	..	..	..	..	..
30- 4-41	..	..	19·4	19·8	..	23·6	20·5	..	..	..	18·2	1·22	0·68
9- 5-41	..	..	..	..	..	..	..	14·1	19·8	14·8	..	..	..
18- 7-41	26·4	23·2	..	..	..	..	..	..	..	..	..	..	..
29- 7-41	..	..	23·9	27·7	..	23·8	25·1	..	..	..	27·3	0·25	0·13
8- 8-41	..	..	..	..	..	..	..	27·1	36·6	31·9	..	..	..
17-10-41	31·0	54·7	..	..	..	..	..	..	..	..	..	..	..
27-10-41	..	..	35·9	51·8	..	41·9	27·4	..	..	..	39·1	0·04	0·18
6-11-41	..	..	..	..	..	..	..	..	36·1	33·8	..	..	..
15- 1-42	32·4	40·3	..	..	..	..	..	..	..	..	..	..	..
28- 1-42	..	..	18·7	14·8	..	14·0	20·0	..	..	..	21·6	0·13	2·44
4- 2-42	..	..	..	..	..	..	..	20·0	16·8	17·8	..	..	.

The means of the dry-matter percentages for the various harvesting periods over 24 months show clearly defined seasonal trends, there being a strongly negative correlation with rainfall. Figure 14 illustrates how the period of minimum rainfall in each year is followed by high dry-matter content,

whereas the peak value for rainfall coincides with minimum dry-matter content of the grasses.

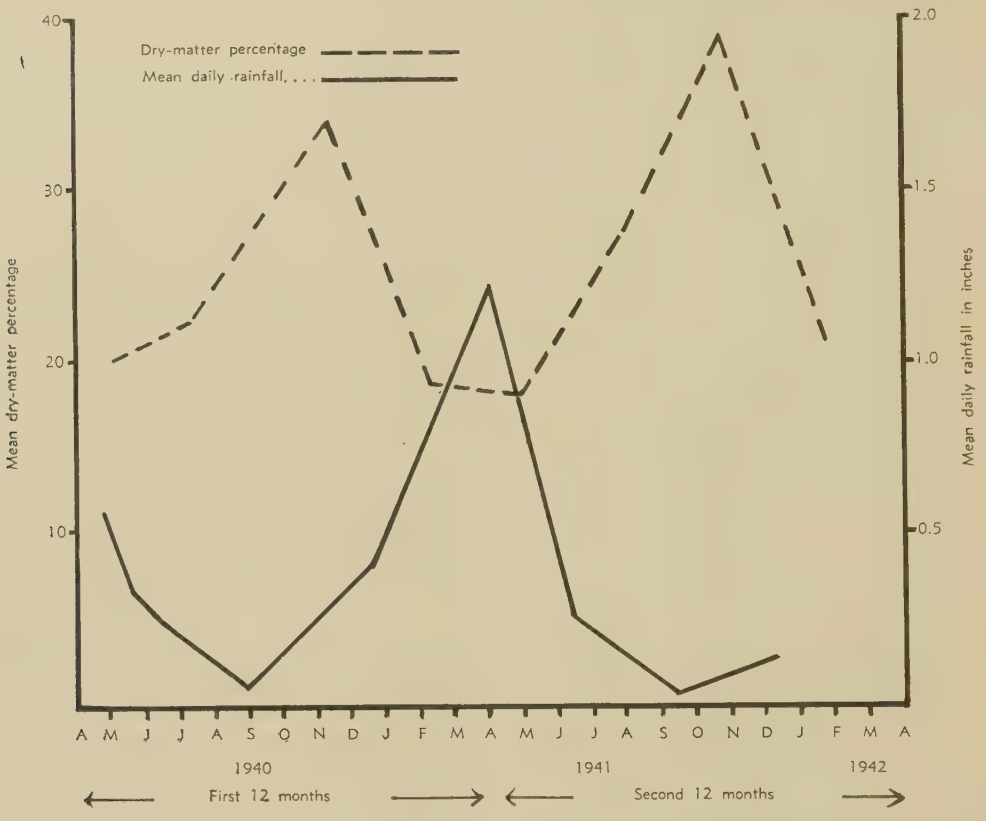

FIG. 14.

Showing the Relationship Between Mean Dry-matter Content and Mean Daily Rainfall for Grasses cut at Monthly Intervals.

Figure 15 shows the relationship between mean dry-matter percentage and mean yield under a system of monthly cutting. It will be noted that high yield tends to be associated with low dry-matter, but where low dry-matter content results from high precipitation, yield is not always high. Rainfall in the wet belt of coastal northern Queensland can be so high that—as already pointed out—instead of promoting productivity it actually retards it to a considerable degree. Thus, in the first three months of 1941 the rainfall amounted to 81·07 inches, and in April a further 41·19 inches was recorded: The mean yield of 3·30 tons in February dropped to 0·68 tons green matter per acre in April, which is equivalent to a reduction of over 79 per cent., although the corresponding dry-matter percentages showed little change at 18·9 and 18·2, respectively. Table 22 shows that up to and including the "zenith" period of the first 12 months there is a negative correlation between mean dry-matter percentage and mean yield, but this is broken in the subsequent "rapid decrease" period. The highest dry-matter percentage recorded

in Table 22 during the first 12 months is 34·2, corresponding to the latter portion of the "low" period of productivity, and the lowest figure is 18.9 per cent., representing the "zenith" period.

The dry-matter percentages for the second 12 months show the marked influence of two factors: excessive rainfall in April, and reaction to fertilizer application during the latter part of the year. Excessive rainfall in April, acting concurrently with the "rapid decrease" period of productivity, and following three months of high rainfall, caused a very severe drop in yield, although the dry-matter percentage remained very low at 18.2. At the commencement of the "low productivity" period the dry-matter percentage rose to 27.3 (see Table 22), and towards the end of the period a further increase to 39.1 occurred, although the mean yield rose slightly as a result of fertilizer action becoming effective. In the "zenith" period there was a rapid drop in dry matter to 21.6 per cent., indicating the operation again of a negative correlation between dry-matter percentage and yield.

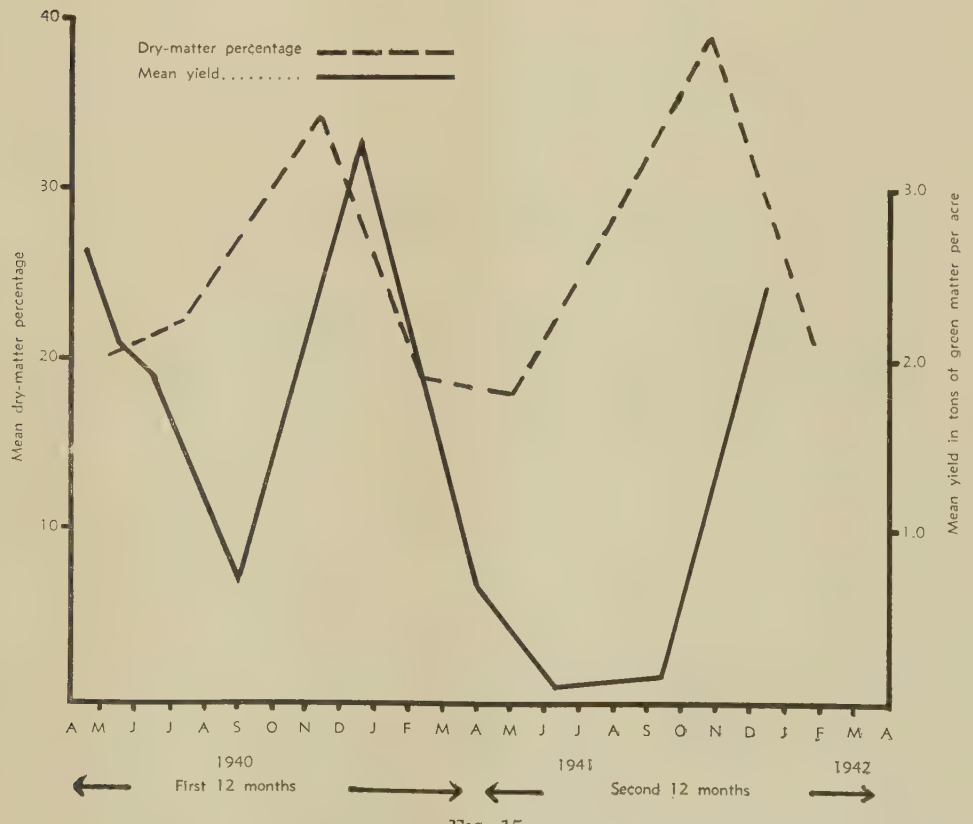

Fig. 15.

Showing the Relationship Between Mean Dry-matter Content and Mean Yield of Green Matter for Grasses cut at Monthly Intervals.

Two-monthly Cuts.

Table 23 shows the variation in dry-matter percentage under a two-monthly cutting rotation. The figures show a similar seasonal trend to that observed under monthly cuttings, but there is a noticeable increase in the dry-matter percentages of herbage cut at the same season of the year. Actually, the cutting of the monthly and two-monthly rotations coincides on two occasions only, and the respective mean dry-matter percentages are given below:—

Date of Cut.	Mean Dry-matter Percentage.	
	Cut Monthly.	Cut Two-monthly.
28/5/40	21·1	24·3 (10 grasses)
5/6/40		
14/6/40		
15/1/42	21·6	25·2 (9 grasses)
28/1/42		
4/2/42		

These figures show an increase in dry-matter in favour of the longer cutting rotation of 3·2 per cent. and 3·6 per cent. respectively. The remaining figures in Table 23 are not strictly comparable because of differences in the

Table 23.

SHOWING DRY-MATTER PERCENTAGES—TWO-MONTHLY CUTS.

Date of Cut.	*Panicum maximum* var. *trichoglume.*	*Paspalum dilatatum.*	*Hyparrhenia aucta.*	*Panicum maximum* var. *coloratum.*	*Brachiaria purpurascens.*	*Brachiaria decumbens.*	*Chloris gayana* No. 6586.	*Pennisetum clandestinum.*	*Panicum maximum* var. *typica.*	*Melinis minutiflora.*	Mean Dry-matter Percentage.
28- 5-40	24·2	18·4	..	..	..	..	..	..	..	..	..
5- 6-40	..	..	24·2	23·0	36·7	23·4	26·6	..	..	..	24·3
14- 6-40	..	..	..	..	..	..	..	20·3	24·2	21·9	..
23- 9-40	38·0	36·7	..	..	..	..	..	..	..	..	..
1-10-40	..	..	32·8	38·3	39·1	39·1	34·4	..	..	..	37·3
11-10-40	..	..	..	..	..	..	..	36·0	42·1	36·7	..
21- 3-41	26·4	24·8	..	..	..	..	..	..	..	..	..
30- 1-41	..	..	19·3	21·5	18·1	19·5	23·4	..	..	..	22·9
10- 2-41	..	..	..	..	..	..	..	23·4	25·9	25·5	..
20- 5-41	24·1	24·3	..	..	..	..	..	..	..	..	..
30- 5-41	..	..	28·2	22·2	..	20·3	20·9	..	..	..	22·8
9- 6-41	..	..	..	..	..	..	..	20·9	24·5	20·1	..
18 -9-41	32·2	38·9	..	..	..	..	..	..	..	..	..
26- 9-41	..	..	34·9	34·8	..	33·9	34·6	..	..	..	37·3
7-10-41	..	..	..	..	..	..	..	46·6	42·0	38·1	..
15- 1-42	32·1	38·7	..	..	..	..	..	..	..	..	..
28- 1-43	..	..	28·8	22·3	..	18·7	28·8	..	..	..	25·2
5- 2-43	..	..	..	..	..	..	..	14·8	22·3	20·4	..

dates of cutting, but it can be stated that, in general, the longer cutting rotation tends to produce an increase in dry-matter content, a result in accordance with expectation.

Three-monthly Cuts.

Figures for the dry-matter percentages covering the various harvesting periods are given in Table 24. Data on the mean dry-matter percentages of cuts where dates of harvesting of the various rotations coincide are summarized below:—

Date of Cut.	Mean Dry-matter Percentage.		
	Cut Monthly.	Cut Two-monthly.	Cut Three-monthly.
25/ 6/40			
5/ 7/40	22·4	..	28·5 (10 grasses)
15/ 7/40			
23/ 9/40		37·3	37·5 (10 grasses)
1/10/40	..		
11/10/40		36·7	38·1 (9 grasses)
21/ 3/41	..	25·6	30·1 (2 grasses)

Table 24.

Showing Dry-matter Percentages—Three-monthly Cuts.

Date of Cut.	*Panicum maximum* var. *trichoglume.*	*Paspalum dilatatum.*	*Hyparrhenia aucta.*	*Panicum maximum* var. *coloratum.*	*Brachiaria purpurascens.*	*Brachiaria decumbens.*	*Chloris gayana* No. 6586.	*Pennisetum clandestinum.*	*Panicum maximum* var. *typica.*	*Melinis minutiflora.*	Mean Dry-matter Percentage.
25– 6–40	24·2	18·0	..	..	..	..	..	..	..	..	..
5– 7–40	..	..	32·8	28·1	28·5	25·0	34·4	..	..	..	28·5
15– 7–40	..	..	..	..	..	..	..	32·8	31·6	29·3	..
23– 9–40	32·0	39·8	..	..	..	..	..	..	..	..	..
1–10–40	..	..	35·2	39·8	39·1	36·7	35·9	..	..	..	37·5
11–10–40	..	..	..	..	..	..	..	37·5	39·1	39·8	..
20–12–40	30·2	34·1	..	..	..	..	..	..	..	..	..
31–12–40	..	..	44·2	34·1	35·5	35·9	44·1	..	..	..	33·4
10– 1–41	..	..	..	..	..	..	..	25·7	26·8	23·6	..
21– 3–41	29·5	30·8	..	..	..	..	..	..	..	..	..
31– 3–41	..	..	32·8	19·5	18·0	24·2	25·8	..	..	..	28·0
10– 4–41	..	..	..	..	..	..	..	26·6	36·7	35·9	..

These figures reveal the same tendency for the dry-matter percentage to increase with the length of the cutting rotation as was observed in the comparison of the monthly and two-monthly cutting rotations. The mean dry-matter percentages for ten grasses harvested during the period 23-9-40 to 11-1-40 corresponding to the two- and three-monthly rotations show an increase

of 0·2 per cent. only in favour of the longer rotation. An examination of the individual dry-matter figures in Table 24 indicates that the main cause of this small difference is due to two grasses—*Panicum maximum* var. *typica,* which has a high dry-matter content of 42.1 per cent. in the two-monthly rotation, and *P. maximum* var. *trichoglume,* with a comparatively low dry-matter content of 32·0 per cent. in the three-monthly cut. A comparison of the respective mean dry-matter percentages after the elimination of these grasses gives a difference of 1·4 per cent. For the cut taken on 21-3-41 two grasses only—*Panicum maximum* var. *trichoglume* and *Paspalum dilatatum*—can be compared, but their average dry-matter percentages show a substantial increase of 4·5 for the three-monthly cut. Variations in individual dry-matter percentages, such as that of the two Guinea grasses cited above, are bound to occur due to differences in functional periodicity and other factors. Taking the results as a whole, however, the figures presented demonstrate clearly the increase of dry matter with the longer cutting rotation and the negative correlation of dry-matter percentage with yield over a considerable portion of the year; that is, except for the periods previously mentioned, where, because of the depressing effect on yield of the prolonged wet season characteristic of the Innisfail area and the effect of fertilizer application made in the second 12 months, this negative correlation does not persist. In this connexion it is of interest to note Stapledon's (1924) statement relative to the percentage of dry matter in green fodder under temperate conditions: "Thus in a general way maximum yield of dry matter tends to be associated with minimum or approaching to minimum percentage of dry matter in total produce." The same association holds good for the summer rainfall area of the very wet belt of coastal northern Queensland, except for the periods already commented upon. Paterson (1935) working in the West Indies with four different cutting rotations on elephant grass, Guatemala grass and Uba cane found that herbage cut when the rainfall was comparatively light had a much lower moisture percentage than in the wet season and also that "produce from the longer cutting rotations tends to have a higher dry-matter content than from the plots harvested more frequently."

The increase of dry-matter content in accordance with the length of the cutting rotation is shown graphically in Figure 16 for the first period of 12 months and in Figure 17 for the second 12 months.

In Figure 17 it will be noted that the mean dry-matter percentage figures for herbage under monthly cutting are apparently higher at one stage than the figures for two-monthly cutting. Actually this it not so, as the difference is caused by the non-coincidence of the dates of harvesting of the two rotations at the period of "low productivity." The two-monthly rotation shows a higher dry-matter content than the monthly cut until October, 1941, and there is no doubt that, if a cut had been possible in late October or early November under the two-monthly rotation, the dry-matter content would have exceeded that of herbage from the monthly cut.

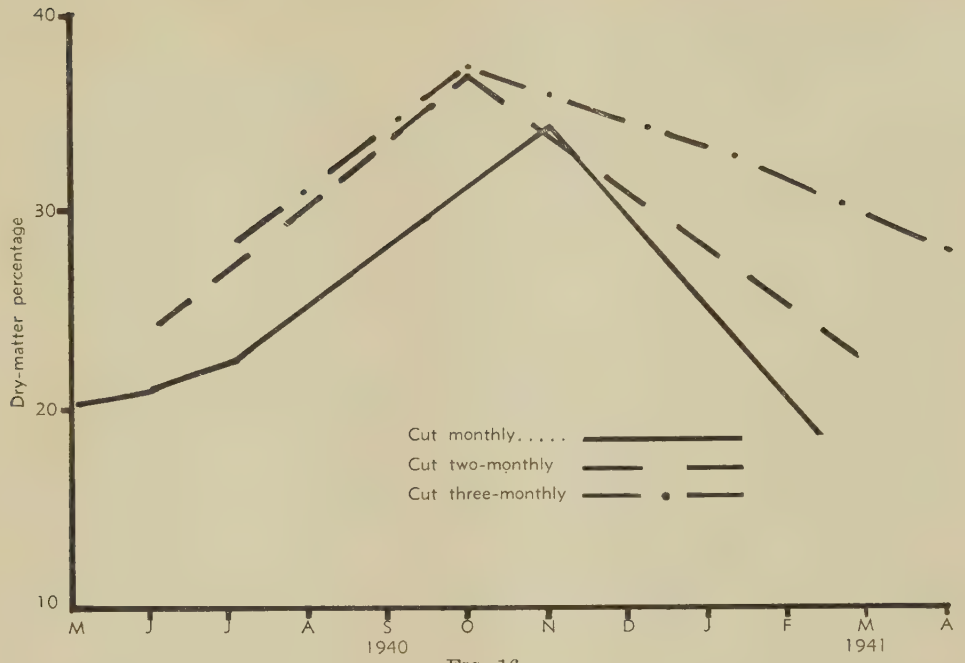

FIG. 16.

Showing the Mean Dry-matter Content of Ten Grasses at Intervals over the First 12 Months of Monthly, Two-monthly and Three-monthly Cutting Rotations.

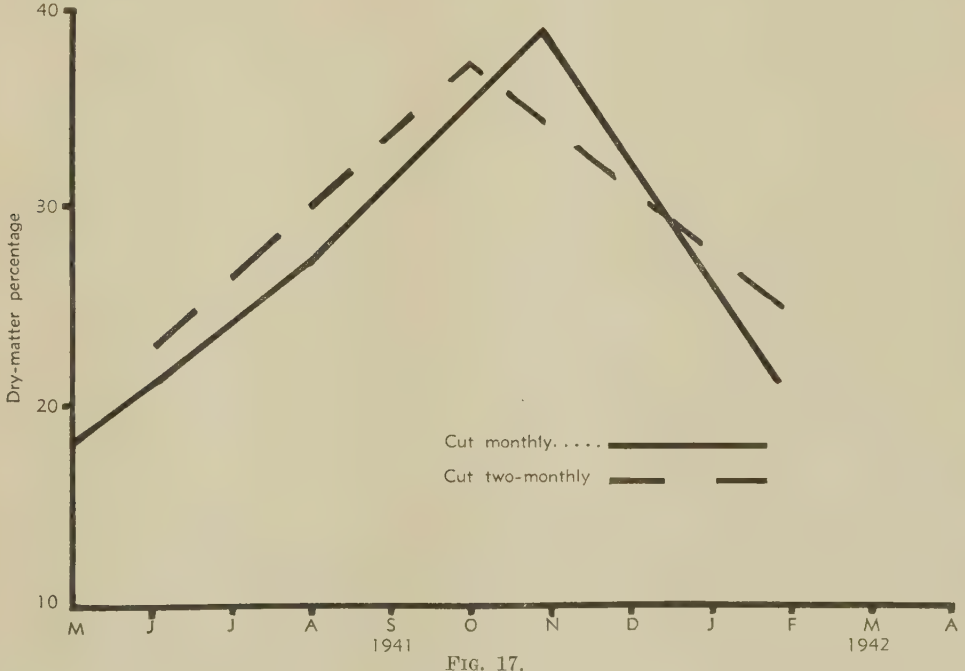

FIG. 17.

Showing the Mean Dry-matter Content of Nine Grasses at Intervals Over the Second 12 Months of Monthly and Two-monthly Cutting Rotations.

The exceptional behaviour of *Cynodon plectostachyum* (African star grass) calls for special mention. In Table 25 the dry-matter percentages of *C. plectostachyum* under each cutting rotation are compared with the corresponding mean figures for five grasses in series II.: *Hyparrhenia aucta, Panicum maximum* var. *coloratum, Brachiaria purpurascens, B. decumbens* and *Chloris gayana* No. 6586. The outstanding fact arising from an examination of this table is the high dry-matter percentage of *C. plectostachyum* under each rotation and in each productivity period. In particular, the high dry-matter percentages during the period of "low productivity" are noteworthy. Thus, under the monthly rotation the dry-matter percentage for the latter portion of the "low productivity" period is 48·4, or 15·5 per cent. above the mean; under the two-monthly rotation the figure is 49.2, or 12.5 per cent. higher than the mean; and under the three-monthly rotation a dry-matter percentage of 53·1 is reached, which is 15·8 per cent. more than the mean. However, during the "zenith" period there is a considerable fall in the dry-matter content of *C. plectostachyum,* although in no cutting rotation does the figure actually reach, or fall below, that of the mean of the five grasses in the same series.

Table 25.

SHOWING DRY-MATTER PERCENTAGES OBTAINED WITH *Cynodon plectostachyum* (AFRICAN STAR GRASS) UNDER MONTHLY, TWO-MONTHLY, AND THREE-MONTHLY CUTTING ROTATIONS COMPARED WITH THE MEANS OF FIVE GRASSES IN SERIES II.

Cut Monthly.			Cut Two-monthly.			Cut Three-monthly.			
Date of Cut.	*Cynodon plectostachyum.*	Mean of 5 Grasses in Series II.	Difference.	Date of Cut.	*Cynodon plectostachyum.*	Mean of 5 Grasses in Series II.	Difference.	Date of Cut.	*Cynodon plectostachyum.*	Mean of 5 Grasses in Series II.	Difference.
6– 5–40	28·9	20·0	+8·9	..	..	..	..	..	..	..	..
6– 6–40	30·5	22·0	+8·5	6– 6–40	33·6	26·8	+ 6·8	..	..	..	..
5– 7–40	31·3	21·8	+9·5	..	..	..	..	5– 7–40	36·7	29·8	+ 6·9
1–11–40	48·4	32·9	+15·5	1–10–40	49·2	36·7	+12·5	1–10–40	53·1	37·3	+15·8
30– 1–41	20·7	16·9	+3·8	30– 1–41	21·9	20·4	+ 1·5	31–12–40	43·9	38·8	+ 5·1
..	..	..	..	..	..	..	..	31– 3–41	27·3	24·1	+ 3·2

FIELD OBSERVATIONS.

Throughout this investigation notes were taken on all the grasses prior to each cut. Field observations, in fact, formed a most important part of the experiment and the salient features are summarized below.

Condition of Grasses at the Discard Cut.

The condition of a grass when the first cut is taken will have a very important bearing on its future behaviour. Stapledon (1924), referring to productivity studies with temperate grasses, states: "A system started when the plants have attained to full heading will outyield a system started prior to such a date." Under tropical conditions it is even more important that a grass be properly established before cutting or grazing is undertaken because of the

absence of a "dead season," which, in the temperate zone, ensures a rest period and enables the storage of production reserves in the plant. Care was taken in this investigation to obtain a full stand of well-established, vigorous plants in each plot prior to the first or discard cut. Planting was carried out mainly in early January and, as the summer in northern Queensland extends from January to March inclusive, this period is optimum for growth and satisfactory establishment because of the prevailing high temperatures and copious rainfall characteristic of a summer rainfall area. The following notes summarize the observations made on the various grasses:—

Series I. Cut 27-3-1940.

Panicum maximum var. *trichoglume*: Seeding heavily, about 6 ft. high.

Panicum maximum No. 1202: No sign of seeding, about 7 ft. 6 in. high.

Panicum maximum No. 3783: No seed production, about 5 ft. high.

Cenchrus ciliaris: Seeding very heavily, 3 ft. 6 in. high.

Digitaria milanjiana: Several flower heads; about 3 ft. 6 in. high.

Urochloa bolbodes: Seeding heavily; about 1 ft. 6 in. high.

Paspalum dilatatum: Seeding heavily; seed heads heavily infested with ergot; about 1 ft. high.

Series II. Cut 4-4-1940.

Brachiaria decumbens: Well-developed seed heads; 3 ft. 6 in. high.

Hyparrhenia aucta: Well-developed seed heads; 4 ft. high.

Panicum maximum No. 1200: Seed heads well developed; about 6 ft. high.

Panicum maximum var. *coloratum*: Seed heads mature; 5 ft. 6 in. high.

Brachiaria purpurascens: No seed heads; runners 12 ft. long; herbage about 3 ft. high.

Chloris gayana No. 6586: No flower formation; 3 ft. high.

Cynodon plectostachyum: No sign of flower formation; about 2 ft. 6 in. high.

Series III. Cut 15-4-1940.

Panicum maximum var. *typica*: Excellent growth; about 7 ft. high; seeding.

Melinis minutiflora: Giving excellent bulky growth about 3 ft. 6in. high.

Chloris gayana No. 6585: Seeding fairly heavily; about 3 ft. high.

Pennisetum clandestinum: A very scanty growth about 1 ft. high; no sign of flowering.

Inflorescence Emergence.

A summary of field observations of inflorescence emergence in 11 grasses is given in Table 26. The observations are particularly interesting because they indicate the wide range of variation which occurs in the group of grasses selected relative to the incidence, intensity and duration of inflorescence production, and the association between this latter and yield with certain grasses.

Table

RECORD OF INFLORESCENCE EMERGENCE OVER A

KEY: c.f. commencing to flower. h.f. heavy flowering.
l.f. light flowering. v.h.f. very heavy flowering.
v.l.f. very light flowering. m.f. moderate flowering.

Grass.	Period of establishment.			Low.			Rapid increase.			Zenith.		
	1st cut.	2nd cut.	3rd cut.	4th cut.	5th cut.	6th cut.	7th cut.	8th cut.	9th cut.	10th cut.	11th cut.	12th cut.
Panicum maximum var. *typica*	c.f.	nil	nil*	nil	v.l.f.	l.f.	l.f.	v.l.f.	nil	nil	nil	v.l.f.*
Panicum maximum var. *coloratum*	v.h.f.	c.f.	v.l.f.	v.l.f.	l.f.	l.f.	v.l.f.	nil	v.h.f.	m.f.	l.f.	l.f.
Panicum maximum var. *trichoglume*	v.h.f.	m.f.	m.f.	nil	m.f.	m.f.	v.l.f.	v.l.f.	l.f.	m.f.†	m.f.	m.f.
Paspalum dilatatum	c.f.	l.f.	v.l.f.	nil	nil	nil	nil	nil	v.l.f.	m.f.	v.h.f.	l.f.
Hyparrhenia aucta	c.f.	m.f.	v.l.f.	nil	nil	v.l.f.	l.f.	l.f.	v.l.f.‡	m.f.	v.l.f.	m.f.
Brachiaria purpurascens ..	c.f.	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil
B. decumbens	c.f.	nil	nil	nil	nil	nil	nil	c.f.	l.f.	l.f.	nil	v.l.f.
Chloris gayana No. 6586 ..	c.f.	c.f.	v.h.f.	l.f.	m.f.	h.f.	h.f.	v.l.f.	nil	nil	nil	nil
Chloris gayana No. 6585 ..	nil	m.f.	m.f.	l.f.	v.h.f.	h.f.	h.f.	v.l.f.	nil	v.l.f.	nil	v.l.f.
Pennisetum clandestinum ..	nil	nil	nil	nil	v.h.f.	l.f.	v.l.f.	nil	nil	nil	nil	nil
Melinis minutiflora	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil

* Very heavy seeding under three-monthly cuts.
† Heavy seeding under two-monthly cuts.
‡ Heavy seeding under three-monthly cuts.

26.

PERIOD OF TWO YEARS UNDER A SYSTEM OF MONTHLY CUTS.

Rapid decrease.			Low.				Rapid increase.		Zenith.			Remarks.
13th cut.	14th cut.	15th cut.	16th cut.	17th cut.	18th cut.	19th cut.	20th cut.	21st cut.	22nd cut.	23rd cut.	24th cut.	
nil	nil	nil	nil	nil	nil	v.l.f.	nil	nil	v.l.f.	nil	l.f.†	Monthly cutting would appear to be too frequent for heavy inflorescence production, but a marked periodicity occurs in the longer rotations.
nil	nil	nil	v.l.f.	nil	v.l.f.	v.l.f.	nil	h.f.	v.l.f.	m.f.	v.l.f.	Well marked periodicity—the times of free inflorescence development mark the commencement of the zenith period of production in each year. Note the rapid inflorescence developmen' during the 30 days prior to the 9th and 21st cuts respec tively.
v.l.f.	l.f.	l.f.	l.f.	nil	nil	v.l.f.	l.f.	h.f.	l.f.	h.f.	h.f.	Well marked periodicity.
v.l.f.	nil	nil	nil	nil	nil	nil	nil	l.f.	h.f.	l.f.	v.h.f.	Marked periodicity.
v.l.f.	nil	nil	nil	nil	v.l.f.	v.l.f.	l.f.	v.h.f.	l.f.	l.f.	v.l.f.	Monthly cutting is too frequent to allow of satisfactory flower production. Heavy seeding in the three monthly rotation preceded the zenith period of production.
nil	..	..	..	..	..	..	..	..	..	..	..	Very shy flower production.
nil	nil	nil	nil	nil	nil	nil	nil	l.f.	v.l.f.	v.l.f.	v.l.f.	Shy flower production.
nil	v.l.f.	v.l.f.	v.l.f.	v.l.f.	h.f.	v.h.f.	m.f.	v.l.f.	nil	nil	nil	No marked periodicity and no correlation between inflores-cence production and yield.
v.l.f.	v.l.f.	v.l.f.	v.l.f.	v.l.f.	v.l.f.	v.l.f.	h.f.	l.f.	nil	nil	nil	No marked periodicity and no correlation between inflores-cenee production and yield.
nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	No marked periodicity and no correlation between inflores-cence production and yield.
nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	Inflorescence formation can be prevented if the period between cutting or grazing does not exceed two months over the first two years.

P. maximum var. *typica* shows by its behaviour under monthly cutting that a period of 30 days is not sufficiently long to allow of heavy inflorescence production. However, under the longer rotations, especially the three-monthly cut, there is a well-marked periodicity in the times of flower-head formation. Furthermore, the results show that each of the varieties and strains of *Panicum maximum* included in the study possesses this periodicity of inflorescence production, in which *free* inflorescence emergence marks a period of *high* yield. To take a specific example: *P. maximum* var. *typica* under a system of three-monthly cutting produced its heaviest crop of seed heads at the harvest on 15-7-40 (3rd cut in Table 26), when the peak yield equivalent to 11·4 tons of green matter per acre was obtained, which represents 41·5 per cent. of the annual crop. The next heavy seeding took place prior to the cut on 10-4-41 (12th cut) when a yield equivalent to 7·1 tons of green matter per acre was recorded. Under a two-monthly rotation the heaviest seeding occurred before the cut taken on 6-4-42 (24th cut in Table 26), when a crop equivalent to 10·7 tons of green matter per acre was harvested, which represents 50·8 per cent. of the yield for the year. This association between inflorescence production and yield has been stressed by Stapledon (1924) in his work on temperate grasses. It is of considerable interest, therefore, to note that under conditions in the wet belt of tropical Queensland a similar relationship is apparent with some grasses.

P. maximum var. *coloratum* is outstanding among the grasses examined for its well-marked periodicity of inflorescence production, in which the times of free inflorescence emergence marked the commencement of the "zenith" period of production in each 12 months. *P. maximum* var. *trichoglume* and *Paspalum dilatatum* also show a marked periodicity of inflorescence production which is linked with the periods of greatest growth.

Hyparrhenia aucta does not display satisfactory inflorescence production, when the system of cutting is too frequent, as under the monthly rotation. In the two- and three- monthly rotations, however, there are periods of heavy seed production. A flush of flower heads occurs in both of these rotations prior to the first harvest after establishment. In the three-monthly rotation heavy seeding preceded the cut taken on 31-12-40, when the yield was equivalent to 9.1 tons of green matter per acre—the highest of the four cuts covering the 12 months. Again, in the two-monthly rotation heavy seeding preceded the cut on 30-1-41, which was equivalent to 13·6 tons of green matter per acre, representing 42.6 per cent. of the yield for the first 12 months. However, the heavy seeding which occurred before the cut on 1-4-41 was *not* associated with high yield, but with low vitality. The stools of *H. aucta* were almost dead and the heavy seeding was the provision made for the survival of the grass. The heavy and continuous rain of the wet season in 1941 almost resulted in the death of this species, and it was not until late August that signs of recovery were observed. The heavy seeding prior to the 11th and 12th cuts in the two-monthly rotation were associated with high yields, equivalent to 5·2 and 8·6 tons of green matter per acre respectively. It can be concluded that *H. aucta* shows a periodicity of inflorescence production which is associated with high yield, but the grass also exhibits exceptional behaviour relative to

seeding, as it is rather intolerant of the high moisture content of the soil which occurs during the prolonged wet season typical of the Innisfail area.

Brachiaria purpurascens is too shy in the production of flower heads under all cutting rotations for any information to be collected relative to periodicity. *B. decumbens* is also shy in flower head production under monthly cutting; under the longer rotations heavy seeding occurred in the first 12 months, but not in the second year. There is a well marked periodicity of inflorescence production with high yield in this grass. Under the two-monthly rotation heavy seeding occurred prior to the cut taken on 30-1-41, when the yield was equivalent to 13·5 tons of green matter per acre, representing 29·7 per cent. of the total for 12 months. In the three-monthly rotation heavy seeding preceded the cut taken on 1-4-41, which was equivalent to 17·6 tons of green matter per acre or 33·1 per cent. of the total for the year.

The two strains of *Chloris gayana* both produce flower heads freely, but there is no periodicity with the flush periods of growth. In fact, the lack of any association between inflorescence production and yield is additional evidence of the unsuitability of the climatic conditions of coastal northern Queensland for the satisfactory development of this species.

Pennisetum clandestinum is quite different from the other grasses in that flower formation takes place in short herbage only, and the following notes were taken on the flowering of this grass: "After the cut on 12-9-40 flowering commenced. There was little evidence of flowering on the 13th, but as each day passed flower production increased up to the 19th, when a count showed 26 flowers present per square foot. The number of flowers remained about constant until the end of September. It was noted that the stigmas only were exserted; no anthers were visible." This observation agrees with the description given by Edwards (1937) of the Rongai ecotype, and Parker (1941), writing of conditions in South Australia, observed that "stigmas exsert in abundance, although the anthers appear to remain entirely within the florets." There is no association between flowering and yield in this experiment and the ecotype of Kikuyu grass described above.

Melinis minutiflora under a system of monthly and two-monthly cutting extending over two years, and three-monthly cutting for one year, did not produce any flower heads. Actually, this grass seeds very heavily when it is spelled for a time in the grazing paddocks, but under cutting treatments in this experiment no flower heads were produced. It was also observed that this grass appeared to recover slowly after cutting.

Condition of Grasses in April-May, 1942, After Two Years under Monthly Cutting.

Panicum maximum var. *trichoglume*: Large stools; soft leaf 8 in. high; light flowering; healthy; two stools out of a total of 20 are showing a marked loss in vitality.

P. maximum var. *coloratum*: Large-sized stools; tillering well; soft leaf 3 ft. high; very light flowering; healthy.

P. maximum var. *typica*: Large stools; tillering well; soft leaf 3 ft. high; very light flowering; healthy.

Paspalum dilatatum: Stools giving moderate cover only; leaf 8 in. high; heavy flower production, but badly infested with ergot.

Hyparrhenia aucta: Moderate tiller production only; this grass suffered severely under monthly and two-monthly cutting from April-July, 1941; growth has been very uneven; many of the stools show marked lack of vigour and one has already died.

Brachiaria decumbens: Poorish cover; leaf 8 in. high; light seeding; towards the end of April, 1942, several bare patches were observed, although in the two previous months the cover was good.

Chloris gayana No. 6586: Very poor stools; leaf 1 ft. 6 in. high; moderate seeding; heavy weed infestation.

Chloris gayana No. 6585: Small stools; leaf 2 ft. high; poor cover; moderate seeding; heavy weed infestation.

Pennisetum clandestinum: Poor cover; leaf 6 in. high; plots invaded by *Ageratum conyzoides*.

Melinis minutiflora: Stools only partly covered with leaf, 3 in. long; discard rows show much more vigorous growth; leaf 15 in. high.

Urochloa bolbodes: Medium-sized stools; fair cover; leaf 6 in. high; no leaf discoloration; no seed.

Digitaria milanjiana: Medium-sized stools; poorish cover; leaf 3 in. high; rather scanty growth in second year from July to September.

A comparison of tillering intensity, stool size and general growth under the three rotations showed that the drastic system of monthly cutting had a marked restrictive influence, which became very noticeable during the "rapid decrease" and "low" periods of productivity. These findings are in agreement with those of various workers in the temperate zone and of Paterson (1935) on tropical grasses.

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THE TREATMENT OF LITTLE-LEAF OF DECIDUOUS FRUIT TREES.

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SUMMARY.

1. Following the identification of little-leaf of deciduous fruit trees in the Stanthorpe district as a disorder due to zinc deficiency, experiments were conducted to ascertain the best methods for the application of zinc as a corrective of the disease.

2. A winter spray consisting of a 5 per cent. or a 2½ per cent. solution of zinc sulphate in water gave satisfactory response within a few months; little control was obtained with a 1 per cent. solution.

3. Spring foliage sprays containing up to 2 per cent. of zinc sulphate had little or no immediate beneficial effect on affected trees.

4. Winter sprays not only produced an earlier response in affected trees than did spring sprays, but had more lasting effects. Thus, if a winter spraying was omitted there was only a slight reversion to the condition in the second year after treatment, whereas if foliage sprays were used and spraying was omitted one year the disorder reappeared completely in the following year.

5. Broadcasting and ploughing-in of 5 lb. zinc sulphate around an affected tree produced beneficial effects in the second and third year after treatment. Tree injections were unsatisfactory.

6. The application of the experimental results to orchard practice is discussed, and it is concluded that winter spraying is preferable to spring spraying, to the application of zinc compounds to the soil, and to tree injection. Probably, winter spraying and soil treatment in conjunction would be preferable to winter spraying alone in the early treatment of the disorder.

INTRODUCTION.

The presence of little-leaf in the Stanthorpe district was first referred to in 1928 and its increasing importance led to a considerable amount of field experimental work being undertaken by departmental officers. A report on such work carried out between 1934 and 1937 (Morwood, 1937) furnished considerable evidence of the response of affected trees to zinc treatment and appeared to establish the identity of the disorder as little-leaf. Nevertheless, even in 1937, additional information was still required as a basis for final recommendations on the method and frequency of treatment and on the quantity of material required under Stanthorpe conditions. A continuation of the little-leaf experimental work in a number of apple orchards was therefore decided

on and it has supplied much of the required information. This paper accordingly has as its objective the presentation and discussion of the experimental data secured over the five-year period from 1937 to 1941. Certain of the data secured prior to 1939 were reported in an earlier paper (Ward, 1939).

That the importance of the problem fully justified the additional experimental work is supported by the fact that during the last few years little-leaf has become increasingly prevalent in a number of varieties of fruit trees in the Stanthorpe district until now it is present in trees growing on each of the local granitic soil types, and every succeeding year it appears in many previously healthy orchards. Apples have been more frequently affected than other deciduous fruits, but little-leaf has also become quite common in pears and stone fruits. However, although suspicious symptoms have been noted in grape vines, its presence therein has not been definitely established. A disturbing feature of the trouble is the frequency with which it has made its appearance in young, vigorous orchards during either the pre-bearing or early-bearing stage, as well as in mature, full-bearing orchards which had apparently been healthy in the past.

THE INFLUENCE OF ZINC ON PLANT NUTRITION.

The fact that zinc is one of the trace elements which is essential for the proper nutrition of a wide range of economic plants has been amply demonstrated by research in many countries, an insufficient supply of this element having been established as being responsible for serious functional disorders in several species of fruit trees, e.g., little-leaf of deciduous fruits and mottle-leaf of citrus.

Several workers, notably H. S. Reed and his associates in the United States (1935, 1936, 1938, 1939), have shown that in both these disorders there is a characteristic and profound disorganisation of a biochemical and a physical nature in the cytology of affected leaf tissues. Symptoms of interference with metabolic activity include the lack of chlorophyll, the necrosis of large areas of cells within leaf tissues, the disruption of carbohydrate synthesis, and changes in non-living substances within the cell, particularly tannins. Linked with these symptoms are others involving alterations in the structure of leaf tissues, the most notable of which are an abnormal elongation of the cells of the palisade parenchyma, and compacting of those of the spongy parenchyma, in which the necrotic areas mentioned above are usually present. A reduction in the number and size of plastids also occurs. The general effect of these derangements in leaf tissues is seen in the well-known outward symptoms of zinc deficiency, the most conspicuous of which are leaf mottling and dwarfing.

The application of zinc compounds to affected trees results in the accumulation of zinc in the tissues, and a considerable degree of restoration of metabolic processes follows. For example, the treatment of mottled citrus leaves with zinc sulphate is followed by a resumption of cellular activity, with a consequent return to the normal appearance and functioning of cell bodies such as the nucleus and chloroplasts (Reed and Defrenoy, 1935; Reed and

Parker, 1936). With the development of the latter bodies chlorophyll reappears in the leaves and mottling vanishes; but although zinc restores normal functions to affected tissues it does not change their abnormal structural characteristics. For instance, it does not alter their dwarfness, but without further treatment, and so long as the zinc supply remains unexhausted, new growth, whether of leaf or shoot, is normal in all respects.

METHODS OF SUPPLYING ZINC TO ZINC-DEFICIENT TREES.

Since the initial demonstration of the part played by zinc in the control of little-leaf, research, both overseas and in Australia, has been concerned largely with methods by which this element might be applied most effectively, and in the course of this work a wide range of zinc compounds and a diversity of methods of application have been studied. Foremost among the methods tested are those involving the application of various forms of zinc directly to the tree itself, for treatment through the soil appears to have met with only limited success under certain soil conditions. Attempts to supply zinc directly to trees have been made with zinc sulphate and zinc oxide, applied to the foliage or as dormant-period sprays, or introduced into holes bored in the tree trunk; metallic zinc pieces driven into the trunk and branches have also been experimented with (Chandler *et al.*, 1934; Chandler, undated); whilst dusts consisting of zinc oxide, zinc sulphide or metallic zinc have been tested on the foliage of citrus for the treatment of mottle-leaf (Parker, 1938).

EXPERIMENTAL METHODS EMPLOYED AT STANTHORPE.

The technique employed in the experiments discussed in this paper aimed at placing their results on a quantitative basis, and all were of the randomized block type in which each treatment was replicated eight times, the unit of treatment being a single tree showing definite symptoms of the "little-leaf" stage (Plate 1) of the disorder. On each treated tree affected leader branches were marked by label at the commencement of each experiment, and as a general rule results were based on the subsequent history of these branches. Since it is invariably the terminal portions of such branches that show the symptoms of the disorder most plainly, annual growth measurements were confined to the length of terminal shoots, but counts were also made of affected branches. In the latter case leaf mottling alone was not considered a conclusive symptom unless it was associated with the "little-leaf" condition.

These methods were not completely satisfactory from a statistical point of view because of considerable inconsistency of response within certain treatments, variation in degree of disease incidence, and the occurrence of cases of temporary apparent recovery in untreated plots; furthermore, in some experimental plots growth was generally erratic and adversely influenced by factors other than zinc deficiency. Thus uniformity between trees in each block was less than desirable and in consequence standard errors were high, but the data

nevertheless served very well to express quantitatively what was evident from visual examination.

Plate 1.

Symptoms of little-leaf. Left, normal spring growth. Right, shoot showing "little-leaf" stage.

RESULTS OF METHOD-OF-APPLICATION EXPERIMENT.

Most of the Stanthorpe experiments provided data relative to the suitability of different methods of treating trees with zinc, but one in particular was designed to enable this aspect of the problem to be studied. This experiment was begun in 1937 on 56 eight-year-old Jonathan and Granny Smith apple trees all affected by little-leaf but otherwise apparently in normal health. Details of the treatments applied are shown in Table 1, whilst their effect on shoot growth and incidence of the disorder are presented in Tables 1, 2 and 3, which summarize the results of three seasons' observations. In this and in all other

Table 1.

SHOWING PROGRESSIVE GROWTH RESPONSES BY APPLE TREES AFFECTED BY LITTLE-LEAF AFTER DIFFERENT METHODS OF TREATMENT WITH ZINC. EACH FIGURE IS AN AVERAGE FOR EIGHT TREES.

Details of Treatments.	Date Applied.	Terminal Growth on Affected Leader Branches. (Inches per Tree.)		
		1937. (Before Treatment.)	1937–38.	1938–39.
1. Winter Spray—				
50 lb. $ZnSO_4$/100 galls. water ..	30 July, 1937	16·0	65·1	96·0
25 lb. $ZnSO_4$/100 galls. water ..	28 July, 1938			
2. Winter Spray*—				
50 lb. $ZnSO_4$/100 galls. water ..	30 July, 1937	16·1	79·1	118·7
25 lb. $ZnSO_4$/100 galls. water ..	28 July, 1938			
3. Injections—2 litres 0·125 per cent. $ZnSO_4$ solution	22 Oct., 1937	8·5	15·8	42·2
4. Spring foliage spray—10 lb. $ZnSO_4$ and 5 lb. hydrated lime/100 galls. water	10 Nov., 1937 9 Nov., 1938	9·9	16·6	62·7
5. Soil application—5 lb. $ZnSO_4$ per tree	15 Sept., 1937	17·2	51·1	85·8
6. Soil application—2½ lb. ZnO per tree	15 Sept., 1937	14·6	29·3	49·5
7. Untreated	..	15·2	26·7	43·4
Significant differences (5 per cent. level)		.. ..	32·1	52·5

* Applied immediately after pruning.

Stanthorpe experiments discussed in this paper commercial quality chemicals were used in the preparation of the sprays.

Prior to treatment there was obviously little terminal growth on affected branches, the average length of these shoots being between 3 and 5 inches as compared with 30 inches on unaffected trees. Responses resulting in the restoration of normal shoot growth quickly followed some treatments, while others produced but little improvement.

Table 2.

SHOWING AVERAGE INCREASE IN LENGTH OF TERMINAL SHOOT GROWTH ON AFFECTED LEADER BRANCHES.

Treatments. (As in Table 1.)	Average Increase in Length per Shoot.	
	1937–38.	1938–39.
	(Inches per Shoot)	
1	14·0	21·1
2	15·6	21·9
3	4·5	11·0
4	4·5	15·1
5	7·7	14·2
6	4·5	11·0
7	3·2	8·5
Significant differences (1 per cent. level)	7·7	8·6

Table 3.

SHOWING NUMBER OF LEADERS AFFECTED BY LITTLE-LEAF AT PROGRESSIVE STAGES OF THE EXPERIMENT.

Treatments. (As in Table 1.)	Number of Leader Branches Affected by Little-leaf.		
	1936–37. (Before Treatment.)	1937–38.	1938–39.
1	25	2	0
2	33	6	0
3	37	32	20
4	30	26	8
5	39	21	7
6	34	28	18
7	37	35	27

Untreated Plots.

The data indicate that during the three-year period there was on untreated trees an average improvement in shoot growth and some reduction in the number of affected branches (Treatment 7, Tables 1, 2, and 3). These figures are, however, rather misleading, for there was not by any means a general improvement in the trees; in some of them shoot growth increased a little, but more than half of them showed a steady and rapid decline until many branches had begun to die back from the top; some of these trees became affected in every branch (Plate 2). The transitory nature of the disorder in some of these trees was doubtless due to fluctuations in the availability of naturally-occurring zinc, arising perhaps from seasonal variations in soil moisture and other soil conditions. It is certain that similar changes in the incidence of little-leaf occurred on some of the treated trees irrespective of treatment, and this fact contributed partly to the high standard error appertaining to the experiment and must be borne in mind in assessing the effects of different treatments.

Winter Spray Treatment.

When a zinc sulphate spray at a strength of 50 lb. in 100 gallons of water was applied in July, 1937, there was a remarkable renewal of growth on all 16 sprayed trees in the following October. This new growth appearing on the previously affected branches was evidently normal in all respects, and the new shoots for the most part were comparable with those on unaffected branches. Throughout the growth period they were apparently devoid of "little-leaf" symptoms, but during the summer months signs of mottling appeared on eight out of the 58 labelled branches on the treated trees. At the close of the growing season the average length of terminal shoots on the marked branches was 21 inches as compared with 4 inches in the previous season. The new growth on affected leader branches sprayed during the winter was significantly greater than that on untreated branches (Tables 1 and 2).

With reference to treatment 2, which comprised a winter spray applied initially a few hours after pruning, it was thought that the zinc sulphate

solution would readily enter the plant tissues through the pruning cuts. Trees so treated responded very well, as is indicated in Table 1, but when the trees were pruned a year later it was found that where the solution had contacted the cuts it had penetrated some distance—up to 15 inches—down the branch

Plate 2.

Showing condition representative of that of some of the untreated experimental apple trees. Note the die-back stage reached by some branches.

and had killed a thin strip of tissue therein (Plate 3). Though the injury was not severe it was undesirable, and in later work winter sprays were applied either before pruning or not less than two weeks afterwards.

After the initial treatment in 1937, winter sprays were again applied prior to pruning in July, 1938, but their strength was reduced to half that of the previous year. The following spring brought an even better response than that of the year before, a particularly satisfactory feature being its

completeness, for all branches recovered and added terminal shoots up to 30 inches in length. Once again growth on plots receiving this treatment significantly exceeded that on control plots, and was more consistent than that on plots receiving any other treatment.

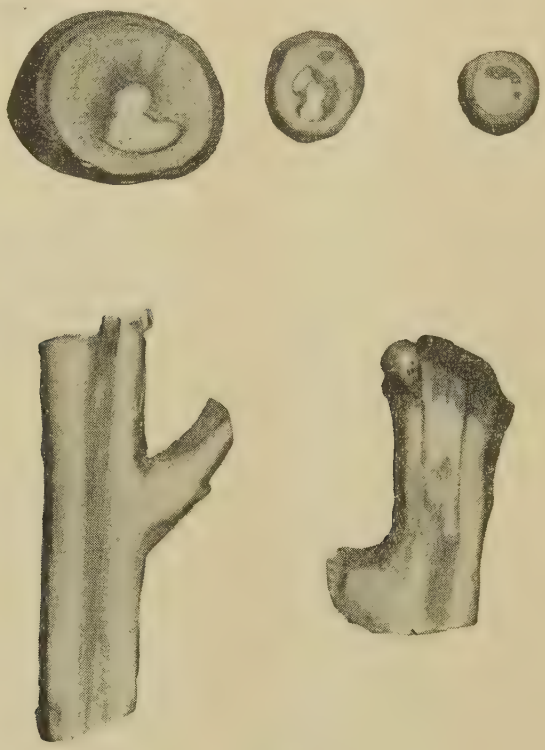

Plate 3.

Showing sections through branches in which wood tissue was killed by 5 per cent. zinc sulphate spray solution applied immediately after pruning.

Spring Foliage Sprays.

A foliage spray consisting of 10 lb. zinc sulphate, 5 lb. hydrated lime, and 100 gallons of water was applied in November, 1937, and the treatment was repeated one year later. The initial application was not followed during that season (1937-38) by any observable response; nearly all labelled branches bore the usual well-marked symptoms of little-leaf, including stunted leaves and shoots as well as mottling, and terminal shoots failed to add appreciably to their length (Treatment 4, Tables 1, 2, 3).

During the second season (1938-39), when the spray was again applied, there was an appreciable reduction in the number of branches showing "little-leaf"—from 26 to 8 (Table 3)—and shoot growth appeared much better than in the previous year. Some trees showed fair improvement, but several others failed to give anything but a short-lived response, and one severely affected tree did not improve at all. This inconsistency in behaviour indicated that

the 10–5–100 foliage spray was decidedly inferior to the winter spray, even though rather less inconsistent results were obtained with foliage sprays in an experiment in which different concentrations of zinc were tested, and which is reported later in this paper.

Soil Treatment.

An examination of data from plots which received a single application of 5 lb. zinc sulphate or 2½ lb. zinc oxide broadcast and ploughed in around each tree in September, 1937 (Treatments 5 and 6; Tables 1, 2, and 3) suggests that the former treatment may have been responsible for an appreciable amount of recovery and some improvement in growth two years later, although the difference between this treatment and the control is not significant. Five of the eight treated trees showed a marked improvement by the second year, but the remaining three responded very slightly, if at all, in that time. In the third year after treatment (1940) the three unimproved trees were apparently responding to a slight degree, and the other five maintained their improvement. This result seems to indicate that zinc eventually became available from the soil application in sufficient quantity to produce beneficial effects. The possibility of still better responses with heavier or more frequent soil applications suggests itself, particularly as it has previously been noted that apple trees in acid soils generally respond far more readily to soil treatment than those on neutral or alkaline soils, in which zinc apparently rapidly becomes fixed and unavailable (Chandler *et al.*, 1934; Chandler, undated). Stanthorpe soils have a pH value of approximately 5. Soil application of commercial zinc oxide at the rate of 2½ lb. per tree was apparently ineffective in correcting little-leaf.

Tree Injections.

Two litres of 0.125 per cent. zinc sulphate (A.R.) solution were injected into the trunks of each of eight trees in October, 1937, by a technique based on that used by Roach (1936) for injecting nutrient solutions into fruit trees. This treatment eliminated some mottling and slightly stimulated growth on branches directly above the auger holes into which the injections were made, but some trees were wholly unresponsive to the treatment even two years after its application.

Further Observations.

The history of this experiment and others not discussed in detail, subsequent to 1939, serves to confirm the earlier observations made on the efficiency of the winter spray treatment. By 1939 a number of trees which had either been untreated or had failed to respond to treatment were very severely affected by little-leaf; some completely lacked terminal growth, and many leaders were dying back from the top. Eleven of these trees, having a total of 59 affected branches, on which the total terminal growth was 385 inches, were sprayed early in August, 1939, with 25 lb. zinc sulphate in 100 gallons of water. In the following November only three branches showed any little-leaf symptoms, and by the end of that growing season these 59 branches had 1,105 inches of top growth. Plates 2 and 4 show the condition reached by some of the control trees by the third year from the commencement of the experiment, whilst Plate 5 is a photograph

of the same tree as that in Plate 4, taken one year later and after winter treatment with a 2.5 per cent. zinc sulphate spray. The restoration of this tree to full vigour was brought about by a second winter treatment, as is shown in Plate 6. It is noteworthy that even severely affected little-leaf shoots, when left unpruned, invariably added a considerable amount of new growth in the season following the winter spray treatment, and within one or two growing seasons their diameter had increased to normal proportions and they had developed fruiting spurs.

The conclusion to be drawn from the experiment described above is clear. Because of the consistency and completeness of its results the winter spray treatment stands out prominently from the other methods of applying zinc, and is indeed the only one that effected the recovery of all treated trees. It is therefore to be regarded as the most suitable of the methods tested for correcting little-leaf in commercial practice, particularly as the cost of the treatment is comparatively small. The use of a soil application of 5 lb. or more of zinc sulphate per tree in conjunction with winter spraying in the early treatment of little-leaf is a potential means of prolonging the beneficial effects of zinc applications and thus minimizing the frequency of spray treatment. Further information is required on this point.

RESULTS OF STRENGTH-OF-SPRAY-MIXTURES EXPERIMENTS.

Winter Sprays.

The effects of different strengths of winter sprays were observed in two experiments. In the first of these, sprays ranging in strength from 1 lb. to 50 lb. of zinc sulphate per 100 gallons of water, i.e., from 0.1 per cent. to 5 per cent., were applied to mature Jonathan and Delicious apple trees in August, 1938. Subsequent counts of affected branches, made in the following spring, showed the almost complete disappearance of the disorder from trees which had received the 5 per cent. and 2.5 per cent. sprays (Table 4), and the lack of

Table 4.

SHOWING THE EFFECT OF DIFFERENT CONCENTRATIONS OF $ZnSO_4$ WINTER SPRAY ON APPLE TREES. TREES SPRAYED AUG., 1938, UNSPRAYED IN 1939 WINTER.

Treatments.	Number of Affected Branches.		
	1937–38.	1938–39.	1939–40.
1. 5 per cent. $ZnSO_4$ ..	24	0	4
2. 2·5 per cent. $ZnSO_4$ ..	21	1	7
3. 1 per cent. $ZnSO_4$ ..	22	5	9
4. 0·1 per cent. $ZnSO_4$ ..	20	12	17
5. Control	24	16	24

satisfactory response from the two weaker sprays. When these trees were left unsprayed in the winter of 1939, evidence of reversion to little-leaf was seen in the case of all treatments, but this reversion strongly tended to increase as the strength of the sprays decreased.

Additional observations were made in another experiment in which winter zinc sulphate treatments were applied in July, 1939, on eight-year-old Jonathan and Delicious apple trees just commencing to fruit. Prior to treatment little-leaf was severe in the majority of the trees; they were affected to the extent that each of them carried an average of 3 to 4 "little-leaf" branches whose terminal growth was 2 inches in length (Table 5). The application of the sprays was followed in the ensuing spring by a very definite reduction in the number of affected branches and a marked improvement in shoot growth on those trees receiving the 5 per cent. and 2.5 per cent. sprays. The response from these two treatments was such that by the end of the growing season shoots on marked branches averaged 18.9 and 20.2 inches respectively in length, whilst the total amount of top growth on these branches had increased nine to ten times.

Table 5.

SHOWING THE EFFECT OF DIFFERENT CONCENTRATIONS OF $ZnSO_4$ WINTER SPRAY ON INCIDENCE OF LITTLE-LEAF AND ON SHOOT GROWTH ON AFFECTED BRANCHES. TREES SPRAYED JULY, 1939.

Treatment.	Number of Affected Branches.		Total Terminal Growth on Affected Branches (Inches).	
	1938–39.	1939–40.	1938–39.	1939–40.
1. 5 per cent. $ZnSO_4$	35	7	64·2	660·2
2. 2·5 per cent. $ZnSO_4$	40	6	88·2	806·7
3. 1 per cent. $ZnSO_4$	37	36	58·2	228·6

It was evident that the 1 per cent. spray produced little beneficial effect on the trees, for there was virtually no decrease in the number of affected branches. Though there seemed to be some stimulation of shoot growth, it was obvious that the 1 per cent. spray was far less effective in this respect than the two stronger ones, and indeed it gave no worthwhile degree of control of the disorder.

The two groups of observations made from these experiments generally support each other, and lead to the conclusion that the strength of winter sprays cannot be safely reduced much, if at all, below the 2.5 per cent. strength.

Spring Foliage Sprays.

The influence of zinc sulphate-lime and zinc oxide solutions when applied to foliage in spring at various strengths was studied in an experiment which began in 1937 and continued until 1940. The principal observations in this experiment consisted of annual counts of little-leaf affected branches, but yearly records were also made of the amount of top growth on them. The former records alone were of value as a means of indicating the true effects of the treatments, for, although at certain stages of the experiment no signs of little-leaf were discernable in many of the plots, no significant growth responses followed the application of any of the treatments. This primarily arose from the fact that growth in the trees in this experiment was limited by a number of factors of which little-leaf was only one; for example, the trees suffered from

copper deficiency, which was subsequently rectified by a soil application of copper sulphate.

The various foliage sprays were first applied in November, 1937, and a second application was made in November, 1939; the results from the first spraying were observed in the spring of 1938, and of the second in the spring of 1940. For purposes of comparison, a winter treatment was included in the experiment, applications being made in 1938 and again in 1939. The varieties in the experiment were Jonathan, Granny Smith, Delicious, and Gravenstein apples.

The results of the series of observations made in this experiment are summarized in Table 6. Prior to the application of the various treatments the average number of "little-leaf" branches was about three per tree. In the growing season during which the foliage sprays were first applied, 1937-38, no noticeable decrease in little-leaf took place, but 12 months later there was a definite reduction in the incidence of the disorder on all sprayed trees. In that season, i.e., 1938-39, even unsprayed trees showed a slight improvement, and this would seem to indicate that the treatments were not necessarily responsible for the whole of the improvement on sprayed trees. The stronger zinc sulphate sprays showed a slight tendency to be more effective than the weaker solutions. Although the first winter spray had been applied more than eight months after the first foliage sprays, response to all sprays showed at the same time.

Table 6.

SHOWING THE EFFECT OF FOLIAGE SPRAYS ON THE INCIDENCE OF LITTLE-LEAF. FOLIAGE SPRAYS APPLIED 23RD NOV., 1937, AND 24TH NOV., 1939. WINTER SPRAYS APPLIED 3RD AUG., 1938, AND 29TH AUG., 1939.

Treatment.	Number of Affected Branches.			
	1937–38. (Before Treatment.)	1938–39.	1939–40.	1940–41.
Lb. per 100 gallons water—				
1. $2\frac{1}{2}$ $ZnSO_4$: $1\frac{1}{4}$ lime	29	5	25	0*
2. 5 $ZnSO_4$: $2\frac{1}{2}$ lime	20	3	20	2
3. 10 $ZnSO_4$: 5 lime	27	0	15	0
4. 20 $ZnSO_4$: 10 lime	30	1	27	0
5. $2\frac{1}{2}$ Zinc Oxide	30	4	10	2
6. 5 Zinc Oxide	24	4	10	0
7. 25 $ZnSO_4$ (Winter Spray)	19	0	1	0
8. Untreated	25	16	25	25

* Treatment 1 was replaced by a 30-15-100 foliage spray in the spring of 1939.

In order that information on the duration of response might be obtained no foliage treatments were applied in the spring of 1938. That the omission of the sprays in that season was followed by a very considerable reversion to the little-leaf condition in 1939-40 is clearly shown in the table; in several instances groups of similarly treated trees almost completely reverted, and this occurred almost to the same degree on trees which received the strongest spray as on those which received the weakest. In view of the high variability of the

experiment no significance can be attached to the apparently better results given by treatments 3 and 6. The winter spray which had been applied again in August, 1939, once more gave good results.

Plate 4.

Control tree B3, which is representative of a number of the untreated trees three years after the commencement of the experiment. Total terminal growth on the affected branches of this tree in 1939 was 5 inches.

The effects of a second application of the foliage sprays made in the spring of 1939 were observed a year later and these showed, firstly, that in the 1940-41 season there were very few symptoms of little-leaf to be seen on sprayed trees during the spring months although some mottling developed later; and, secondly, that there was no well-marked tendency for the stronger sprays to be more effective than the weaker. Thus the observations made in the 1938-39 season, indicating primarily that spring sprays were able to reduce the incidence of little-leaf 12 months after their application, were confirmed in 1940-41. Since the results given in 1938-39 did not indicate that the $2\frac{1}{2}$-$1\frac{1}{4}$-100 spray (Treatment 1, Table 6) would be effective it was replaced by a 30-15-100 foliage spray in the spring of 1939. This rather strong spray, which was applied purely for observational purposes, caused no foliage injury on any of the treated trees, and its application was followed by a definite response in the spring of 1940.

In assessing the value of spring spray applications, cognizance must be taken of the fact that the response from the 10-5-100 spray used in the experiment of which the results are summarized in Tables 1, 2, and 3 was inconsistent, and for this reason it is considered that this treatment is not satisfactory.

DURATION OF RESPONSE TO TREATMENT.

The practical value of any little-leaf treatment will depend to a considerable extent on the duration of the response obtained from that treatment, and therefore observations made on this aspect of the question of control are now summarized. In treatment by winter spraying the first point of note is that although rather spectacular improvement usually follows a single application there are occasionally a few branches that respond poorly or for a short time only. Sometimes such behaviour may have been attributable to incomplete spraying, but under experimental conditions it is unlikely that this explanation is always valid. In two experiments, symptoms of little-leaf were still discernible on one or more trees after a spraying in winter (see Tables 3 and 5) and it must therefore be assumed that a single application of even the 5 per cent. spray is not sufficient to cause complete recovery.

Plate 5.

Tree B3 photographed in 1940. Sprayed in August, 1939, with 2.5 per cent. zinc sulphate solution. Total terminal growth on affected branches in 1940 was 167 inches.

Whenever sprays not weaker than 2·5 per cent. have been applied in two or more successive winters complete disappearance of little-leaf has been effected for at least the following growing season. If the trees are left unsprayed in the third winter their improved condition is generally maintained, although signs of reversion can occasionally be seen. This indicates that the full effects of winter sprays are probably not maintained for more than two years, and that in order to ensure an adequate supply of zinc a spray application is required every alternate year after the initial applications in two successive years.

Plate 6.
Tree B3 photographed after restoration to full vigour by winter spray treatment.

The effects of spring foliage sprays on apples are but slowly felt, and that they quickly disappear is amply shown by the results of the experiment summarized in Table 6. It happened frequently that the response obtained 11 or 12 months after the spray application lasted only during the spring months and by summer mottling had appeared in the leaves. In several experiments in which foliage sprays were employed a few severely-affected trees showed scarcely any recovery. Perhaps the most important unsatisfactory feature of the treatment by spring spraying is the rapidity and extent of the reversion to little-leaf when a season is allowed to pass without a spray

application being made. This reversion is often complete. It is concluded from these observations that spring foliage sprays are not sufficiently effective to warrant their recommendation for use in commercial practice.

GENERAL OBSERVATIONS.

The experiments reported in the preceding sections of this paper have been concerned with little-leaf in apples only, but experimental work with Williams' Bon Chretien pears and observations on stone fruits have provided additional information on the treatment of the disorder. The experiment on pears indicated that winter treatment and spring foliage sprays were both effective in reducing the trouble, but in each case the stronger spray tested, namely, a 5 per cent. winter spray and a 20–10–100 foliage spray, was apparently more effective than the weaker application. On pears, as on apples, the effects of foliage sprays tended to be less durable than those of winter sprays, and, in general, the response by pears to spray treatments has closely paralleled that given by apples.

Winter spray applications of zinc sulphate on affected stone fruit trees—including Japanese plums, peaches and apricots—have invariably been followed by a marked reduction of little-leaf, if not by a complete cure. Where a strong winter spray (5 per cent.) was combined with a winter-strength lime sulphur (1 in 10) and applied to affected plums satisfactory results were obtained. The mixture of the two ingredients, however, gave rise to a heavy precipitation in the spray vat, and the resultant mixture was at times inconvenient to use. A point of note is that as good results were obtained when the zinc was applied at least partly in precipitated form as when applied as a solution of zinc sulphate in water.

It has been thought that the greater efficacy of winter sprays as compared with foliage sprays was perhaps partly explained by the fact that in the former the trees received the zinc as zinc sulphate in solution, whilst in the zinc-lime foliage spray much of the zinc reaches the leaves in a precipitated state, probably as calcium zincate. Of course, as soon as the water evaporates from the solution of zinc sulphate applied as a winter spray fine crystals of that compound are left on the surface of the bark and buds of the trees, and in the process of repeated solution and recrystallization of the salt by the action of dew, rain and melting frost some of the dissolved zinc sulphate is absorbed into the dormant wood tissues, probably through the lenticels and dormant buds. A similar dissolving and absorbing action apparently takes place when the zinc is deposited on the trees in a precipitated form, as is suggested by the results obtained on plums after treatment with the zinc sulphate-lime sulphur spray referred to in the preceding paragraph.

Leaves receiving a zinc-lime spray must also slowly absorb zinc, as small quantities are dissolved by natural moisture, and there may be some further simultaneous absorption through the bark as well as the buds in the axils of the leaves. Apparently the quantity of zinc taken into the plant tissues in this way is less than that absorbed after a winter spray application, since foliage sprays

on apples give markedly less response than winter sprays. Possibly this is because more zinc is applied in the winter spray, or because the zinc sulphate deposited by the latter has a higher solubility than the calcium zincate or other salt which is deposited by the zinc-lime foliage sprays. This explanation, however, seems scarcely satisfactory, since on citrus trees the zinc-lime spray quickly becomes effective, and, moreover, citrus responds to relatively insoluble materials such as zinc oxide and powdered metallic zinc applied either as sprays or dusts, and the duration of the response can apparently be as long as four years (Parker, 1938.) It seems a safe assumption that the intake of zinc from sprays applied to apple foliage differs considerably from absorption of the same element by citrus foliage. The explanation of this phenomenon can be found only by further investigation.

With respect to the nature of the response produced on apple trees by winter sprays, it seems that no matter how severely a branch may be affected by little-leaf it can be restored to a normal condition so long as shoots and buds remain alive. On an affected branch a terminal shoot possessing normal vigour one year may produce a dwarfed shoot the next, or it may fail to add any new wood growth whatever and exhibit only the typical leaf symptoms of severe little-leaf. If such a terminal is left untreated it may commence to die back in a short time, but spraying with zinc sulphate in winter almost invariably causes healthy renewed growth in the ensuing spring. A treated dwarfed shoot when left unpruned will make vigorous growth from its apical bud and, in the course of a season or two, the originally stunted portion of the branch will increase radially to a normal diameter and in due course will produce fruiting spurs. Severely affected trees which have been untreated for some years will often have died back from the tops of some, if not all, of their leader branches, and the fruit produced will be dwarfed. Subsequent treatment of such trees, involving the removal of dead wood and the application of appropriate zinc sprays, stimulates shoot growth, particularly on terminals, to such an extent that, after several growing seasons, previously dwarfed trees compare favourably with normal ones, and a proper balance can be restored to asymmetrical trees. This stimulation of growth is accompanied by the production of fruit of normal size.

It has been noted that mottling in apple leaves is sometimes of a transitory nature. Apparent response to the spraying of mottled foliage was seen in an experiment in which mottling was appreciably reduced after the application of various strengths of foliage sprays, but an equal amount of reduction occurred simultaneously on unsprayed trees in the same experimental block. Usually mottling becomes intensified in late spring and summer, but that the reverse can be true is also evident.

APPLICATION OF RESULTS TO ORCHARD PRACTICE.

From a consideration of the foregoing experimental data it is clear that spraying with zinc sulphate in winter has produced a faster, more complete, and more enduring response in apple and other deciduous fruit trees affected with little-leaf disease than any of the other treatments applied, and it follows,

therefore, that it must form the basis of practical control recommendations. Such recommendations will necessarily include the application in winter of a zinc sulphate spray of no lower concentration than 2.5 per cent. in two successive years as an initial treatment to restore affected trees to a normal condition; thereafter, an application in alternate years would be required to prevent reversion to the little-leaf condition. Growth on severely affected trees would evidently be more readily stimulated if the strength of the spray used in the first year of treatment were 5 per cent.

The treatment outlined here is applicable to pears and plums, and probably to other stone fruits as well, and should, at a low cost in materials, effectively maintain an adequate supply of zinc to trees requiring this element.

In applying the winter spray it must be remembered that the spray solution will enter fresh pruning cuts and produce a toxic effect on the wood, and it is therefore preferable to apply the spray before pruning, or, if this is impracticable, the application should be delayed for at least two weeks after pruning.

The desirability of a treatment which would remain effective for a longer period than a winter spray is undoubted, but the possibilities in this direction are somewhat limited. The driving of triangular pieces of sheet zinc into the tree trunk appears to have a beneficial effect, but the pieces tend to fall out readily and the physical injury caused to the bark offers a means of entry for bark and wood diseases. A possible alternative method of securing a lasting response in local acid soils is to make an application of zinc sulphate to the soil around the trees, but, in view of the rather slow improvement shown by trees so treated, it would be necessary at the same time to apply a winter spray—which would probably have to be repeated in two successive years—in order to obtain an early response. Once the trees had been treated in this manner the supply of zinc in the soil might keep them free from little-leaf for some years.

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A GANODERMA ROOT ROT OF CITRUS.

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In September, 1942, an unusual root rot of citrus trees was reported from the Gayndah district by Mr. A. W. S. May, Assistant Research Officer. As the root specimens submitted exhibited symptoms not encountered previously in the field or described in literature discussing citrus diseases, an investigation of the cause of the rot was undertaken.

The disease was found on examination of the orchard concerned to occur in a compact group of ten trees of the Beauty of Glen Retreat variety of mandarin budded on rough lemon stock. One tree had been killed and had been uprooted and removed from the orchard some time prior to the writer's first visit to the property. The tops of the other trees exhibited the symptoms usually associated with root rot in varying degrees of severity. Leaves were chlorotic and were being shed and the fruit were small and prematurely coloured. Twigs were dying back, the dieback extending into the larger limbs and so affecting the greater part of the tree. In a few cases, single limbs on trees had not been affected and were bearing normal foliage and fruit. It was found later that such limbs were being supported by a small part of the root system as yet unaffected by the rot. In the case of the tree which had been killed by the disease, every main root was found to be affected by the rot.

The most striking and characteristic symptoms were found on affected roots. The soil, which is of a very sandy type, was tightly encrusted round affected roots of all sizes—from the smallest it was possible to find up to main roots, three inches or more in diameter—and even, in some cases, round the crown and trunk of the stock. The wood and bark exhibited a dry, crumbly rot, and if the sand-encrusted bark were lifted it broke away, leaving a buff-coloured, furry growth of fungous mycelium on the cortex of the root.

Specimens of affected roots were collected and placed in stoppered glass tubes to ensure safety in transit. When examined in Brisbane three days later, the tubes were found to be almost filled with a profuse growth of white fungous mycelium. The fungus was easily isolated from such material in pure culture on potato dextrose agar. No spores were formed but the mycelium was typical of that of a member of the Basidiomycetes. Root specimens taken from the tree which had been uprooted failed to produce any growth of fungous mycelium when pieces were plated on the agar medium, and it is quite probable that the fungus had been killed by exposure to the sun and air.

Fruiting bodies commenced to appear on the stock of an affected tree in January, 1943, after a period of very wet weather, and in March well-developed sporophores were abundant. Several stalked sporophores had been produced from the broken ends of roots left in the soil when the orchardist had uprooted the dead tree mentioned previously, and another tree which was very severely

affected by the root rot had developed several sporophores in the form of brackets growing out from the trunk of the stock (Plate 1).

Plate 1.

Butt of a severely affected citrus tree showing a *Ganoderma lucidum* bracket.

The sporophores of the causal fungus are striking in appearance. In most cases they are stalked and, where two or more occur close together, the pilei may fuse. Grass shoots, twigs, leaves, etc., are often found enclosed by the growing tissue of the sporophores. At first they are soft and rubbery, with a dark-brown, polished stalk and a creamy-white, knob-like pileus. As the pileus enlarges, a light-brown, varnish-like colour develops on the upper surface. Later as the sporophores age, harden and become corky, this shining, varnished appearance covers the whole of the upper surface, the under surface remaining

creamy-white (Plate 2). The brown, verrucose, truncate-oval spores are borne in tubes opening on the under surface of the pileus. The range of measurements of fifty of these spores was $10 - 11\,\mu$ x $6{\cdot}5 - 8\,\mu$. The fungus has been identified as *Ganoderma lucidum* (Leyss.) Karst.

Plate 2.
Mature *Ganoderma lucidum* sporophore from a citrus root.

In the same group of affected trees, a bunch of fused sporophores similar to those found on the broken ends of the roots of the dead citrus tree was discovered in March, 1943, half-way between two citrus trees without any apparent connexion with citrus tree roots. By carefully digging round the base of these sporophores it was found that a solid, cylindrical core of sandy soil, tightly bound together by mycelium, extended to a depth of 18 inches below the surface of the soil, and that it originated from a dead native tree root about 4 inches in diameter (Plate 3).

This root was traced back to an old stump which had merely been burned off below plough depth when the land was cleared. The sapwood of the stump and all of its roots was dry, cream-coloured and crumbly as a consequence of the rot which had developed from the invasion of the tissues by the fungus. The true wood did not seem to be affected by the fungus, but later

it was found that it could be attacked, although the subsequent rot progressed very slowly. From a comparison of the sporophores, spores and mycelium on potato dextrose agar, the fungus affecting this native tree root was identified as being the same as that attacking the citrus roots. Further digging to remove the stump and its roots showed that the roots of affected citrus trees had come into contact with the rotted roots of the stump, the fungus thereby gaining entrance to the citrus roots. This contact seemed to be necessary for infection to take place because, although the roots of the stump passed close to one citrus tree within the group of affected trees without actually making contact with its roots, this tree remained healthy.

Plate 3.

Left hand figure shows young composite sphorophore of *Ganoderma lucidum*. Right hand figure shows point of origin of sporophore on *Eucalyptus paniculata* (?) root. Lower figure shows core of mycelium and soil which connected the sporophore with the root.

Owing to the absence of aerial parts of the native tree, a definite identification of the stump is impossible, but the specific range of trees growing in the vicinity of the orchard and comments by the Division of Forest Products of the Council for Scientific and Industrial Research, by whom a specimen of the root was examined, warrant it being identified as probably *Eucalyptus paniculata* Sm., i.e. the grey ironbark. Two more cases of the death of citrus trees in other orchards, one of Washington Navel oranges on lemon stock and another of Ellendale Beauty mandarins on orange stock, due to the same fungus, have been observed more recently and in each case well-developed sporophores were obtained. In the former case, the native tree host of the fungus has been identified as probably *Eucalyptus gummifera* (Gaertn.) Hochr., the red bloodwood, and in the latter as probably *E. tessellaris* F. v. M., i.e., the Moreton Bay ash or Carbeen. These identifications are uncertain because only roots were available. On the orchard on which the Moreton Bay ash was believed to be the native host tree, plants of the tar vine, *Boerhaavia diffusa* Linn., growing adjacent to the affected trees—which were only two to three years old and had been killed by the root rot—had also been attacked at the root with consequential extensive rotting.

As the most important consideration in this outbreak of root rotting—from the orchardist's point of view—was eradication, the sources of infection were eliminated as completely as possible, all dead and severely affected citrus trees with their rotted roots being dug out and destroyed. The soil was removed from the butts of slightly-affected trees, which were surgically treated to eliminate all affected roots and parts of the butt, and the exposed surfaces were treated with Bordeaux paint or lime sulphur used at a strength of 1 in 6. The butt and roots were left exposed to the sun during the warmer months of the year in an attempt to kill out any fungous mycelium which might have been left behind after the described treatment had been applied. Orchardists were advised not to replant infected areas for at least three years after attacked trees had been removed, it being hoped that the lapse of this period will allow the fungus to die out.

INDEX

★

	No.	Page.
Ants—		
Seed-harvesting and other ants in tobacco-growing districts	3	33
Atherton, D. O. *See* Smith, J. H.		
Banana—		
Nutrition as qualified by development in *Musa cavendishii* Lambert	1	1
Blackford, F. W.—		
Paper on "A Ganoderma root rot of citrus"	4	77
Cartmill, W. J.—		
Paper on "The effects of season, stage of growth, and soil type on the chemical composition of grasses in the Queensland 'wet belt'" ..	2	1
Cassidy, N. G.—		
Paper on "Exchangeable sodium and the physical properties of soils" ..	1	140
Paper on "Natural waters of the Queensland coastal belt"	1	128
Citrus—		
Ganoderma root rot	4	77
Ganoderma root rot of citrus	4	77
Grasses—		
Effect of season and frequency of cutting on productivity	4	1
Effect of season, stage of growth, and soil type on chemical composition ..	2	1
Little-leaf of deciduous fruit trees	4	59
McDougall, W. A.—		
Papers on "An investigation of the rat pest problem in Queensland canefields"—		
"1. Economic aspects"	2	32
"2. Species and general habits"	2	48
"3. Laboratory experiments on food intake and toxicity"	3	1
Musa cavendishii Lambert—		
Nutrition as qualified by development	1	1
Plant Nutrition—		
Qualified by development in *Musa cavendishii* Lambert	1	1
Rats—		
Canefield pests—Economic Aspects	2	32
Canefield pests—Species and habits	2	48
Canefield pests—Food intake and toxicity experiments	3	1

Schofield, J. L.—

Paper on "Effect of season and frequency of cutting on the productivity of various grasses under coastal conditions in Northern Queensland" .. 4 1

Smith, J. H., and Atherton, D. O.—

Paper on "Seed-harvesting and other ants in the tobacco-growing districts of North Queensland" 3 33

Soils—

Exchangeable sodium and physical properties 1 140

Summerville, W. A. T.—

Paper on "Studies on nutrition as qualified by development in *Musa cavendishii* Lambert 1 1

Ward, K. M.—

Paper on "The treatment of little-leaf of deciduous fruit trees" 4 59

Water—

Natural waters of the Queensland coastal belt 1 128

A. H. Tucker, Government Printer, Brisbane

7 104566 120164 7